BUILDING WITH WASTE:
A CREATIVE DIVERSION TOWARDS
MANAGING WOOD PALLET WASTE IN HAWAIʻI

A DARCH PROJECT SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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Dedication

First and foremost, I thank my Lord and Savior, Jesus Christ, for blessing me with the opportunities, the challenges, and growth throughout this arduous experience. Thank you for guiding me each step of the way. I give all praise and glory to you.

I would also like to dedicate the very individuals who have supported me throughout this whole journey, whose love and support have enabled me to achieve what I didn't think I could do. Thank you to my father, Rubinson Intong Sr., for all the discipline you have instilled in me growing up, for working hard and for being there for us. Your tough love and encouragement was a critical influence on many of my success to this day.

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And lastly, I dedicate this accomplishment to my grandmother, whom I miss so very much. We made it Mama.

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Abstract

This project looks to develop second-life waste diversion strategies for wood pallet disposition in Hawai'i through an exploration of various waste building material processes that lead to the creation of remanufactured waste building products. Facilitating this recycling process is the design for a pilot recycling program and facility that will house the necessary processing equipment to produce the said building products. While wood pallet wastes continue to be a prevalent waste stream in Hawaii, produced highly from big-box companies and industrial warehouses, there is a strong DIY culture in our Hawaii communities that either build with or without recycled materials. The objective is then how the design intervention can service these commercial businesses and their wood pallet wastes, and support, equip, and encourage our communities to be a part of the solution.

Part 1 of the research project contextualizes the background of wood pallet waste and waste management in Hawai'i, which will include quantitative and qualitative data from various waste reports. Part 2 investigates applicable product manufacturing strategies for upcycling wood pallet waste through case study research on creative waste building materials. The most applicable and efficient process(s) and building product(s), will be used for primary function and aspects of the pilot recycling facility design. Part 3 focuses on precedent studies of model recycling programs, locally or abroad, aimed to develop a concept collection and facilitation strategy for Hawaii's wood pallet waste. Part 4 and 5 end the project by locating an opportunity site for the placement of the final pilot recycling facility design.

This intervention responds to the need for waste reduction and landfill diversion, by reinjecting value to the life of waste materials, thus averting environmental impact caused by contemporary waste management systems. As the population grows and

urbanization continues to sprawl, more preemptive planning and creative solutions such as this should be considered to prevent further future waste streams, while promoting public awareness, and potentially new socio-economic culture.

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Introduction

Waste is the construct of human interaction with raw materials — our only form of resources — from one stage of being into another, by the application of complex forms of skills and energy. Waste has always been a known substance which neither fitted into the category of natural resources nor that of finished products. Waste was perceived as a by-product, is difficult to be categorized within the of raw vs. configured dichotomy.

For far too long we have lived in a "throw-away" society. We designed industries and cities that generate waste — a potentially valuable resource, only to be buried under mounds of dirt. Generations of this waste management and societal culture have contributed to the global crises we face today. We realize the damages we've created and are paying for it, but we also now understand better how to remedy or at least avert the problem from worsening. Waste is growing to be a vital part of what we define as a resource. We start this shift of perception by acknowledging waste's capacity as the key ingredient or matter from which we can construct new products. Simultaneously, products can be viewed as the material source for other products, beyond its initial life span.

This way of thinking metabolizes opportunities from what is wasted, much linked to urban mining — a recent phenomenon where we embrace the process of reclaiming valuable elements from wasted or undesired products or buildings. This unlocks our understanding of the built environment as the provisional stage of material storage. Cities have passed the age of industrialization and entered the period of recovery — it is this renewal process that provokes the opportunity for a higher order where everything is valuable, and nothing is disposed of. For generations we designed cities to generate waste, now we are designing waste to regenerate our cities.

Worldwatch Institute's prognosis on waste speculates that the world's growing population will make the annual production of a municipal solid waste double by 2025, its volume increasing to 2.6 billion tons per year.[1] The State of Hawaiʻi follows the same suit. With ongoing urban development and future transit transportation and oriented development, the question for how Hawaii can prepare for future waste from these developments must be addressed.

Activation of waste materials has already begun in the past decade, yet there are many more opportunities where waste streams can be better diverted. This research explores the potential of activating waste material for urban construction, looking to the city as a supplier for such matter to energize the concept of circular economy. The project proposes a holistic approach, incorporating industrial, social, and economic principles to create a system where materials live through several states of formation and use over their entire lifespan. This alters society's perception of waste as an undesirable material, to catalysts to build projects and cultivate new culture and communities.

Meanwhile, Hawaii has a special Do-It-Yourself (DIY) culture, with individuals building with recycled materials. There is potential to activate our communities to participate in trends such as tactical urbanism projects. With numerous underutilized, worn down areas across the island, there is potential for interventions initiated by citizens to promote community engagement and identity.

Preemptively to avoid overburdening, the research scope of work will investigate a subset waste material within Hawaii's municipal solid waste streams as the target

[1] Gardner, Gary. *Urbanizing the Developing World*. 2012

material to address. The exploration leverages on principles such as regenerative design and closed-loop systems, to uncover strategies to improve waste recycling, reduction, and diversion. These themes will aid in questioning the ongoing waste streams and contemporary waste management in Hawai’i, and to challenge the status quo with a holistic, hybrid approach. With these principles integrated with the project goals, a small-scale sustainable strategy could emerge that can influence long-term solutions and allow people to become part of the solution, and not the problem.

PART 1 | Research and Analysis

Part 1 Research and Analysis

The focus of this opening chapter is to provide context and baseline knowledge of the issues at hand regarding Hawaii's current and future profile in managing the island's waste. How we can strive for improved resource efficiency and promote the society to be more engaged and accountable for the resources we abuse, starts with a diagnostic performance review of our current waste management systems. We turn to government and city agency final reports on waste management and recycling to initiate this research. The research is oriented to provide details and highlights on specific undermanaged waste streams. A critique of our current performance on such wastes streams will become the jumping point into the core of this project: to improve the recycling or landfill diversion of a selected waste stream. Holistic principles aimed to alleviate these kinds of challenges will be adapted into the latter portions of the research and design application of this project.

Section 1. Hawaii's Opala (Garbage) Challenges

With over 1.4 million residents and 9 million visitors annually, Hawaiʽi continues a high demand for food, fuel, and energy.[2] [3] Imported products enter the islands, bringing with them expendable material that contributes to the island's issues with waste culture and waste management. The consequence; decades worth of waste and trash-filled in mountainsides, adding to the growing greenhouse effect and climate change. In a more recent development, Honolulu is booming with new condominiums, retail, businesses, tower apartments, and transit-oriented infrastructure. Hawaiʽi is left to

[2] United States Census Bureau. *https://www.census.gov/quickfacts/hi.* Accessed October 31, 2018.
[3] Hawaiʻi Tourism Authority. *Annual Visitor Research*. 2017

face the daunting challenge of future waste disposal, especially as our landfill facilities are reaching maximum capacity.

As the urban fabric evolves, uncertainties of political, economic, and environmental conditions may unfold. It's important to note that as cities grow, so should our design for waste management infrastructure. The City and County of Honolulu have yet to activate its potential to produce more improved, sustainable waste recycling systems. The big question is then, what will Hawai'i do for future waste disposal? More importantly, what could we as people do with what we waste?

1.1 Waste management in Hawai'i

Trash is a multi-island problem in Hawai'i, an issue that is addressed using contemporary measures. Landfills such as the Waimanalo Gulch Landfill on the west side of Oahu services most of Oahu's waste, more than 500,000 tons of waste is dumped there each year.[4] Landfills have been the upfront solution to waste management, but other means such as recycling, waste diversion and source reduction helps minimize waste volume. The government of Hawai'i has implemented many policies and initiatives to cultivate waste diversion culture in local businesses and institutions through reuse, reduce, recycle efforts. A few of these recycling programs is the 3-Cart refuse and the HI-5 Beverage Container Deposit Program. The largest refuse recycling operation in Hawai'i is H-Power waste-to-energy plant, diverting the islands garbage through incineration with energy recovery. The operation reduces overall waste volume but produces ash, a by-product of the combustion process that later is disposed of in Hawaii's municipal landfill.

[4] Shimogawa, Duane. *Trash problems not only impacting Oahu.* Hawai'i News Now. 2008

Oahu Waste Composition

To explore opportunities where we can improve our recycling and waste diversion program, we first need to look at what our waste is composed of. We turn to a 2017 municipal solid waste composition study conducted by Cascadia Consulting Group contracted by the City and County of Honolulu. The report details the types of waste materials received from four generating sectors—residential, commercial, residential self-haul, and commercial self-haul, as shown in Table 1. Composition estimates were applied to the disposed quantities to obtain disposal weight estimates by material type.

Table 1. Waste tonnages by sector

Source: 2017 Oahu Waste Composition Study

Figure 1 presents waste estimates by material class for the overall waste composition. Organic waste is the most significant material, accounting for over one-third (36%) of all disposed waste. Paper waste is the next predominant material class, accounting for approximately 23% of disposed waste in Oahu. Following this is Inerts and Construction and Demolition (C&D), materials wastes from building projects.

Figure 1. Overview of Oahu's overall waste composition

Source: 2017 Oahu Waste Composition Study

Prevalent Waste Materials

Part of the Oahu Waste Composition Study documents the frequent waste types or material that appear yearly. In table 2, a list of the top 10 most prevalent material categories within the Oahu's overall waste was gathered from 2016 to 2017. The top two material types are organic-related materials accounting for about one-fifth (20 percent) of the total disposed waste. Uncoated corrugated cardboard is the next most common material category, accounting for almost 7 percent of the waste composition.[5]

To reiterate the initial objectives of this project: address a specific existing waste stream. The 2017 Waste composition study provides us insight into the most common waste materials. This is valuable in detecting an opportunity waste stream to address for this given project. From this top ten list, we can establish the target waste stream

[5] City and County of Honolulu. Oahu Waste Composition Study. 2017

Table 2. Top Ten Most Prevalent Material Categories in Overall Oahu Waste

Source: 2017 Oahu Waste Composition Study

to study further to create better diversion strategies. An initial assessment of this list, pallets or wood-related materials appears to be the more useful and suitable material among the rest for our project. Pallet wastes come in 5th place, composing 5.9 percent, and an approximate 46,722 tons from the 794,368 total tons of waste that year alone. Along with pallets, coming last is treated wood waste.

We can see more of the presence of wood pallet wastes in specific sectors in the following charts and figures. The statistical data delineates not just more evidence of this waste stream but also points out where and how it is being managed. Both residential and commercial sectors produce a quantity of pallet waste, but the commercial sector generates more. This gives insight into the design for a collection program, further explored in Part 3, the program development phase of this project.

Figure 2. Waste composition results by the Residential Sector.

Source: 2017 Oahu Waste Composition Study

Figure 3. Waste composition results by the Commercial Sector.

Source: 2017 Oahu Waste Composition Study

Waste Diversion

Waste diversion allows for waste reduction and attenuation of harmful environmental impacts from landfilling. As mentioned earlier, the H-Power plant is Oahu's largest refuse recycling facility. Waste diversion in Hawai'i includes waste sent to H-Power, where trash is incinerated with energy recovery. The process generates 10% of Oahu's electricity needs.[6] Ash residue from this process gets transported to municipal landfills such as the Waimanalo Gulch in west Oahu. (See Appendix 1 for detailed waste diversion tonnages).

Figure 4. Inside the H-Power plant

Despite being a practical and economical solution, this type of disposal has several disadvantages that include; pollution of surrounding soil and groundwater with toxins, dispersion of methane and other greenhouse gases into the atmosphere, damages to environmental ecosystems. In an article, Suzanne Jones, the recycling coordinator for

[6] Department of Environmental Services. www.opala.org.

Honolulu County, said that dumping Hawaii's trash into landfills is not a sustainable approach for island communities.[7]

Landfills are not long-term sustainable solutions; they carry a string of serious environmental and global ramifications. Post-consumer waste accounts for almost five percent of global greenhouse gas emissions, but methane gases that are escaping from landfills represent 12 percent of total methane emissions. Compared to carbon dioxide, methane gases are 18 times more potent as a greenhouse gas, as stated by the World Bank.[8]

1.2 Improving Hawaii's Waste Diversion through Reuse

According to the State of Hawaii's Open Data portal for Tonnage of Solid Waste Diversion, 2,083,993 tons of materials have been diverted as of January 2017.[9] The state has made it their goal that by 2030, support recovery of materials through multiple or re-purposed uses. Initiatives such as the Aloha+ challenge provide educational resources and programs to accomplish this feat. A primary strategy for material recovery and diverting waste is through Reuse.

The U.S. Environmental Protection Agency's (EPA) defines reuse as the recovery or reapplication of a package, used product, or material in a manner that retains its original form or identity. Reuse is one of the three "R's" of Solid Waste Reduction (Reduce, Reuse and Recycle). Most reuse happens in the private sector including businesses, non-profit organizations, church groups, and through community events. The US Environmental Protection Agency (EPA) indicated that the most effective way

[7] Cooney, Scott. *The Economics of Recycling in Hawai'i.* 2012
[8] Hoornweg, Daniel, and Perinaz Bhada-Tata. *What a Waste: A Global Review of Solid Waste Management*. World Bank. 2012
[9] State of Hawaii's Open Data portal. *Tonnage of Solid Waste Diversion*

to reduce waste is not to create it in the first place. This could also mean to view waste as what is it, but as a valuable resource for creating new products.

Reuse allows extending the life of a product, preventing solid waste from entering landfills, and enable communities to flourish and make the islands a better place to live. Hawaiʻi has many organizations involved in reuse efforts; notable ones include ReUse Hawaii, Goodwill Industries, Salvation Army, and Habitat for Humanity.

On the island of Oahu, the largest C&D recyclers are ReUse Hawaii, a non-profit organization working to reduce waste through building material reuse and recycling. More than one-third of Oahu's waste is construction and demolition debris. The benefits of salvaging material for reuse saves resources and energy, creates jobs, and provides a locally produced resource. Re-use Hawaiʻi has diverted over 11,000,000 pounds of waste from disposal to date and created 43 jobs.[10] The chart in figure 5 below are statistics on construction materials salvaged in 2016.

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Figure 5. Waste Diversion by Type, 2016.

Source: Reuse Hawaiʻi

[10] Re-use Hawai'i. http://www.reusehawaii.org/home.php.

Figure 6. ReUse Hawai'i Warehouse

Circular Economy

The linear process of product consumption to waste has been the bane of the industrial revolution and civilization. Our "throw-away society" has caused some irreversible damage to our environment. Steering civilization away from worsening it, the circular economy describes the concept of reuse and service-life extension of products. Swiss architect Walter R. Stahel, contributed to this contemporary model with his 1982 paper "The Product Life Factor" where he advocated new sustainable strategies and policies in the industry. He was the first to introduce the three R's to product life cycles: Reuse, Repair, and Remanufacture.[11]

Following the same principle is author Girardet, Herbert, with his book *Creating Sustainable Cities.* His belief of circular metabolism paves the way for how modern cities can minimize resource consumption and maximize recycling to use waste as resources for other entities, thus reduces pollution and waste. As opposed to the linear metabolism model (diagramed in figure 7), resources are consumed once and are

[11] The Product-Life Institute. *Product-Life Factor.* 1982

directly disposed of, producing environmentally harmful effects. Girardet argues that waste recycling can significantly reduce urban use of resources, at the same time create many new jobs, materials, architectural designs, and improved urban life.[12] This research project will follow these circular metabolic models as a strategy to maximize the recycling of our target waste material.

Linear-Metabolism System:

Circular-Metabolism System

Figure 7. Diagram resource metabolism systems in cities

Source: Girardet, Herbert. Creating Sustainable Cities. 2001

[12] Girardet, Herbert. *Creating Sustainable Cities.* 2001

Cradle-to-Cradle Principle

This project analyzes several sustainable principles and practices, which will help frame the research process and programming of the final design concept. In their book *Cradle to Cradle: Remaking the Way We Make Things*, William McDonough, and Michael Braungart suggest a logic of production based on a completely closed resource cycle. The design concept was inspired by nature, in which products are created according to the principles of an ideal circular economy. This approach differs from conventional recycling because it is about eco-effectiveness, creating equal economic, social and ecological benefits.[13]

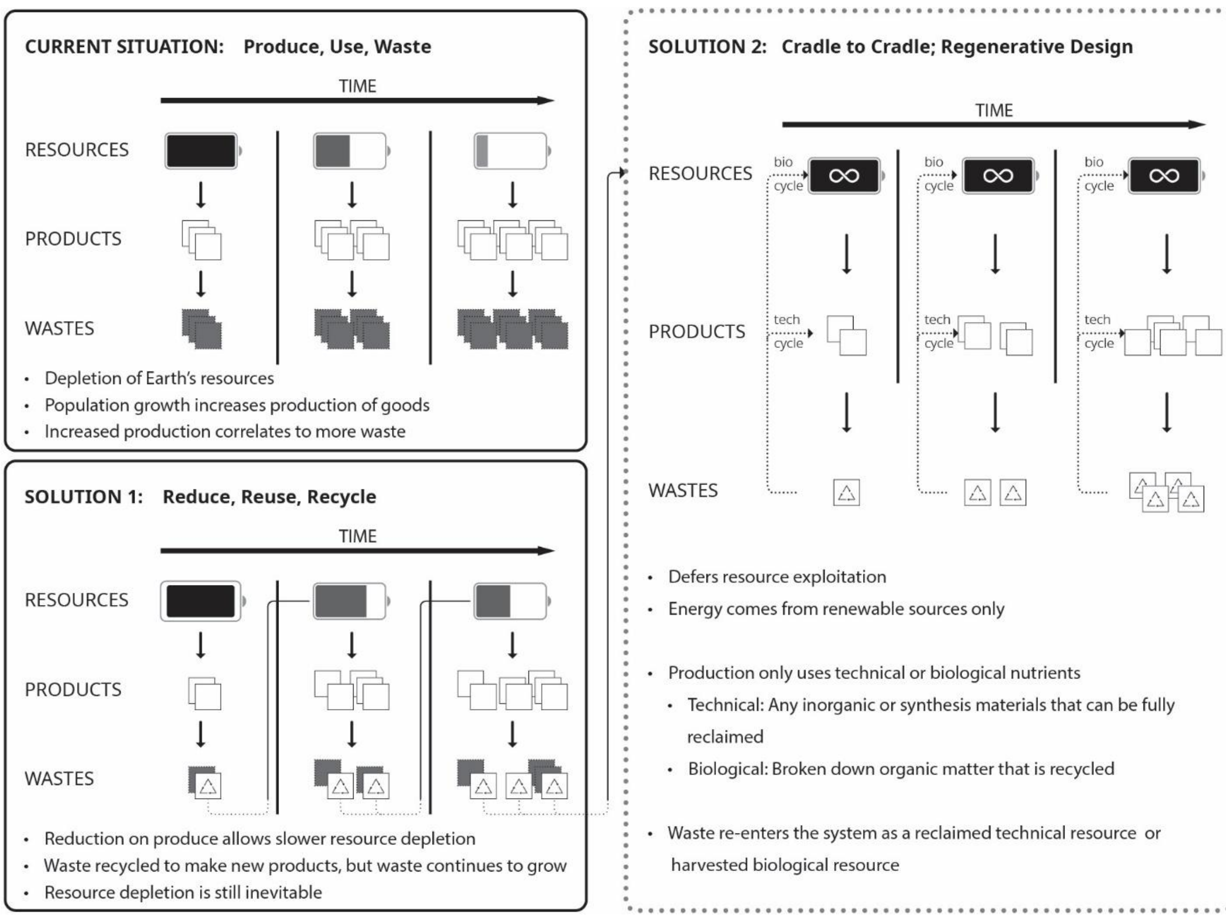

Figure 8. Cradle to Cradle principle comparison

Illustration based on https://en.wikipedia.org/wiki/File:The_Change_in_Sustainability_Framework.jpg

[13] EPEA. https://www.epea.com

Figure 9. Illustration of Cradle to Cradle's nutrient cycles

Source: EPEA

The Cradle to Cradle design concept distinguishes between two distinct nutrient cycles for materials: the biological and the technological. Waste materials in an old product become the "food" for a new product. In the biological cycle, materials are returned to the biosphere in the form of compost or other nutrients, from which new materials can be created. In the technical cycle materials that are not used up during use in the product can be reprocessed to be used in creating a new product. In this research project, the technical cycle is most emphasized in the new approaches to wood/wood pallet wastes.[14]

Compared to the traditional means of product manufacturing and recycling, the Cradle to Cradle solution allows for less resource exploitation by regenerating waste resources into fuel or tools for the next entity. Cradle-to-Cradle products are designed for extended use rather than built-in obsolescence. Waste is no longer wasted but becomes a valuable resource for a closed-loop economy. This holistic framework

[14] EPEA. https://www.epea.com

incorporates ecologic, industrial, social, and economic principles, to create efficient systems that will ideally lead to a waste embracing society, and eliminate the very concept of waste. Figure 8 below diagrams the principle differences in traditional resource consumption and regenerative design.

1.3 Waste Material Scope

The nature of this research is to narrow down to focus on a specific waste stream, to create new waste diversion systems that perform better than what is currently accepted. Evident in the statistical charts in Hawaii's waste composition study examined earlier, wood pallet waste continues to be among one of the more suitable prevalent waste streams to address. This research will explore this phenomenon and document the story behind this continuance of this waste stream and challenging the current management systems that exist. A significant component of the project is seeking innovative ways to build with waste materials, as to put the guiding themes discussed earlier into practice.

Figure 10. Wood pallets sitting in a parking lot of City Mill, Waialae

Section 2. Wood Pallet Industry and Management

As we move on to use wood pallet wastes as our primary material focus, we will uncover further details on the industry behind it, its material properties, lifecycles, potential building applications, and other helpful information that will provoke an alternative second-life uses.

2.1 Wood Pallet Product Overview

Pallets are the most common unit-load platform used across the world and allow for efficient and seamless handling, storage, and transportation of goods. Eighty percent of trade in the United States is carried on pallets.[15] The US alone manufactures approximately 450 to 500 million new pallets each year that then joins the large pool (about 2 billion) of pallets that are in use.[16] Their useful life is rather short, only 3-5 shipments, till they are no longer considered valuable and need to be refurbished or reused, but most likely discarded.[17]

Wood Pallet Lifecycle

Pallet management follows either an open or closed system that is determined by the specific needs of a product distributor, which will then influence the pallet type and its end-of-life disposition. An open-loop practice allows distributors to utilize pallets made with inexpensive wood (typically a softwood) for shipping products, and the ownership and responsibility for disposal of the pallet are transferred to the end-user.[18] All too frequent, pallets through this limited-use practice are landfilled or downcycled.

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[15] Aldraz-Carroll, Enrique, et al. *How do differing standards increase trade costs? The case of pallets.* 2005. 2

[16] Buehlmann, Urs, et al. *Ban on landfilling of wooden pallets in North Carolina: an assessment of recycling and industry capacity.* 2009

[17] Corr, Daryl T. *The Status of Wood Pallet Disposal and Recovery at United States Landfills.* 2000. 1

[18] Mazeika Bilbao, et al. *On the environmental impacts of pallet management operations.* 2011

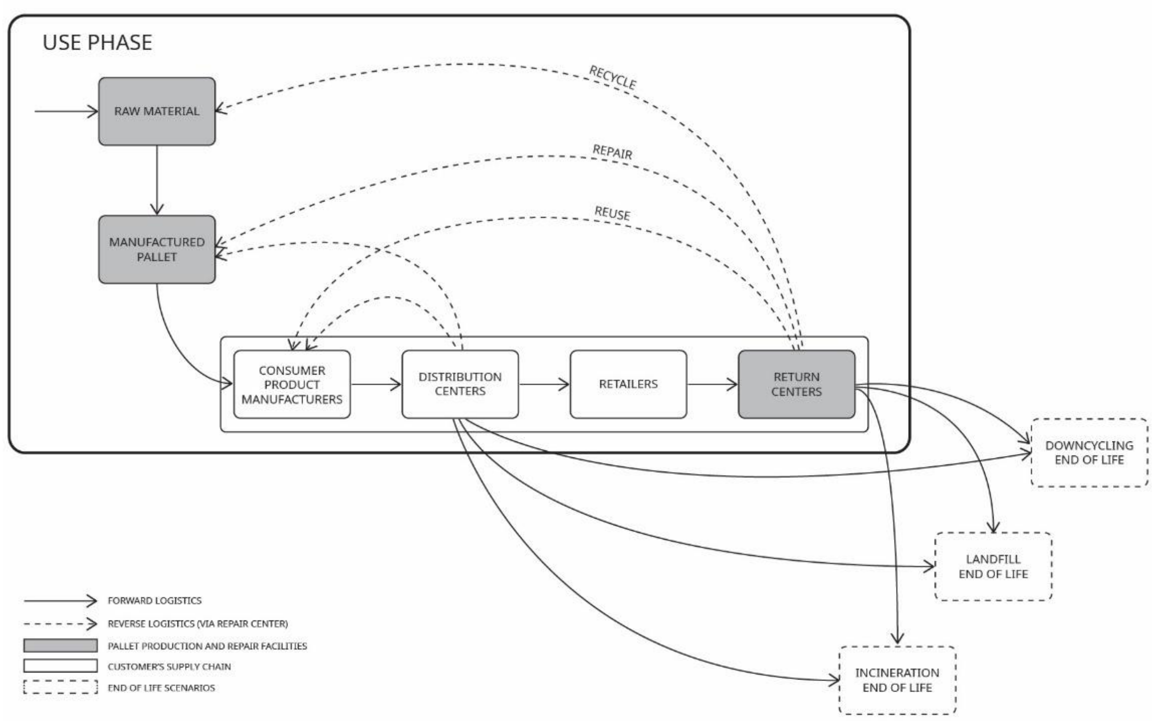

Figure 11. Flow diagram of wood pallet lifecycle in current closed-loop model.

Source: Tornese, et al. 2018

In a closed-loop approach, wood pallets are made with higher grade lumber (typically hardwoods) that allow for more better recovery downstream to be reused in the supply chain to maximize pallet use. Generally, the reverse logistics in this system include collection and prepositioning of wood pallets by third-party providers, cleaning, repair and remanufacturing in return centers.[19] However, every pallet inevitably follows an end-of-life disposition, each a process that produces their own economic and environmental characteristics.

[19] Mazeika Bilbao, A., A.L. Carrano, M. Hewitt, and B.K. Thorn. *On the environmental impacts of pallet management operations.* Management Research Review 1224. 2011

Pallet Types

Worldwide, solid wood takes up about 90 to 95 percent of inventory in pallet manufacturing. The pallet industry is the largest consumer of hardwood lumber within the US, using 33 to 50 percent. There are mainly two types of wood used in the pallet industry: hardwoods and softwoods. Eastern oaks species (Quercus spp.) being the dominant hardwood (22.4%) and southern yellow pine species (Pinus spp.) being the dominant softwood (7.1%).[20]

The majority of the estimated 441 million pallets produced in 2006 were stringer type and not block type pallets. Stringer type pallets have long center structural boards that separate top and bottom deck boards. Wood blocks separate deck boards in block pallet design. Block style pallets are not as popular as they are in Europe. Our survey in the U.S. showed that multiple-use stringer pallets were 41.9% of total pallet production and limited use stringer pallets accounted for 38.2% in 2006.[21]

A variety of pallet sizes were produced in 2006 with 48 by 40 inches being the most common single product (26.9% of production). The production of new 48 by 40-inch pallets was expected to be a greater percentage of overall production since this type of pallet is widely used. However, this pallet type is supported by the recovery and repair industry, and supply from these firms may moderate demand for new 48 by 40-inch pallets.[22]

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[20] Carrano, Andres L, et al. *Characterizing the Carbon Footprint of Wood Pallet Logistics.* 2014. 233
[21] Bush, Robert J, et al. *Hardwoods in U.S. Wood Pallet Production.* 2011
[22] Ibid., 200.

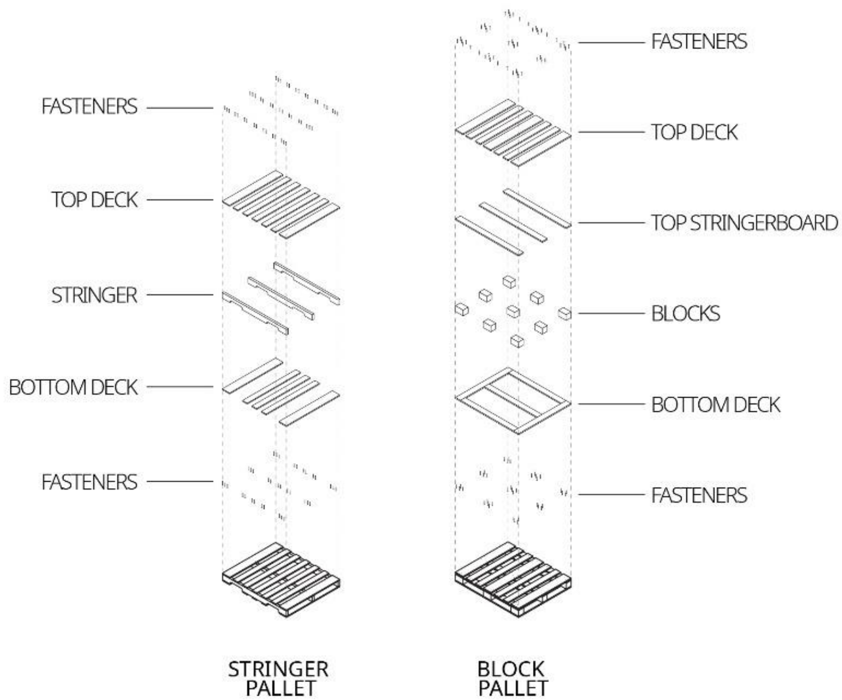

Figure 12. Exploded axonometric diagram of a wood pallet

Wood Pallet Waste History

Based on a 1998 data collection study by Daryl T. Corr on the status of wood pallet recovery at US landfills, his study found that 138 million pallets reached MSW landfills and 40 million pallets in C&D landfills. Of these pallets, 22 million from MSW and 16 million were recovered from C&D landfills typically for mulch, animal bedding, compost or boiler fuel.[23]

[23] Corr, Daryl T. *The Status of Wood Pallet Disposal and Recovery at United States Landfills.* 2000

2.2 Wood Pallet End-of-Life (EOL)

Inevitably, every pallet reaches a point called end-of-life (EOL). Many pallets are used only a few times and end up in a variety of end-of-life scenarios (e.g., landfill, municipal incineration or mulching) while others are repaired and reused many times. There are three main disposition options for wood pallets, each with their own pros and cons. Mulching is the most common form of pallet recycling, but the material recovered is only good for a less demanding application than its original use. Typically considered "downcycling," mulching of wooden pallets also require additional energy for processing and transport, adding to the energy embodied in a wooden pallet.[24] Incineration of wood pallets will result in emissions of greenhouse gases, NOx, SOx, and particulate matter. Also, combusting pallets treated with methyl bromide will liberate toxic and irritating chemicals.[25] The last EOL disposition is landfilling. Table 3 shows the unitary greenhouse gas emission production of all three dispositions, landfilling being the largest generator. Transportation of pallet waste for landfill also contributes to large carbon emissions, as seen in figure 13.

Table 3. Unitary greenhouse gas emissions per end-of-life scenario

[24] Carrano, Andres L, et al. *Characterizing the Carbon Footprint of Wood Pallet Logistics.* 233.
[25] Ibid., 233.

Figure 13. Individual activity contributions during landfilling of wood pallets.

Source: Carrano et al.

2.3 Wood pallet waste history in Hawaii

In Table 4, the City & County Department of Environmental Services has recorded 14,643 tons of wood/wood pallets have been recycled in the year 2017, a number that continues to increase every year for the past decade.[26] As mentioned earlier, there are waste management and recycling facilities that help divert and reduce waste volume before landfilling. Hard data on a recent number of pallet units disposed of in those facilities are minimal. The H-Power plant only weighs the total tonnage as municipal waste. However, according to the a 2006 Waste Characterization Study, about 906 tons of wood pallets have been recorded. The report has also recorded results that Waimanalo Gulch Landfill received 867 tons and Convenience centers with 494 tons.[27]

[26] City & County of Honolulu, Department of Environmental Services. Recycling and Landfill Diversion.
[27] City and County of Honolulu. *Waste Characterization Study*. 2006

Table 4. Total tons of recycled material at H-Power in 2017

Source: City & County Department of Environmental Services

Alternative Wood Pallet EOL

The management of pallets in Hawai'i tends to lean towards a closed-loop approach, because both the incineration or mulching options allow for the creation of new products, e.g., electricity or compost/mulch. However, these forms of recycling are actually more so downcycling, which means the usage of the waste product is suited only for lower quality applications. The project seeks instead, more structural and architectural methods to increase the efficiency of the resource. There is an opportunity here to create alternative options for wood pallet EOL disposition.

One method would be utilizing the lumber from wood pallets to build. Recycling wood from wood pallets to fuel creative projects is not a new phenomenon. With thousands of projects worldwide, it is a popular, free building material that DIY builders enjoy. From a wide variety of projects ranging from furniture to even large-scale structures, the applicability of wood pallets is versatile. This project carries the same spirit.

Figure 14. Pallet House designed by I-Beam Design

The concept for creating a new system for recycling and processing wood pallet waste can be compared to the multiple recycling agencies in Hawaiʻi that deal directly with the material, see figure 15. These large companies have their own unique methods of recycling wood pallets and remanufactured products. The objective for this project, however, is to seek an alternative line of recycling.

The concept calls for an exploration of various waste building material processes that would lead to the creation and application of new structural building applications. The facility that drives this remanufacturing process could have the potential to be a public resource for Hawaiʻi communities, equipping those that have an interest in building but lack the support or tools. The program design could also include residents to sustain the facility's operation. The next section discusses opportunities for how this can be accomplished.

Figure 15. Local agencies that deal directly with wood pallet disposal.

Section 3. Urban Challenges and Opportunities

As discussed in earlier chapters, Hawaii continues to produce wood pallet waste streams that are undermanaged. To provide a new type of intervention into our current repertoire of waste management systems, we must learn to design alternative methods for managing and alleviating the issues on the environment. This section will explore different scales, strategies, and trends such as *tactical urbanism* to develop a preliminary design language that will embody a new recycling operation for Hawaii.

Part of the constraints in establishing a new recycling and processing facility is its economic feasibility and costly building construction. Most of the hesitation that the State of Hawaiʻi has on creating an in-land processing facility for some of our recyclable materials is that we don't produce *enough* waste to construct one. As a result, most of our recyclable materials such as plastics, aluminum, and cardboard, are shipping overseas to foreign countries for remanufacturing. This project aims to prove that it doesn't require a sizeable infrastructural solution, but rather, small-scale, low-cost, tactical interventions.

3.1 Underutilized urban spaces

There are many underutilized urban spaces across Hawaiʻi that could be activated for our design intervention. We turn to underutilized urban areas as a preliminary option situating our concept wood pallet recycling facility. Discussed more in detail in Part 4 of this project, the design seeks to service an area in Honolulu that could benefit from this public resource. Many neighborhood areas in Hawaiʻi suffer from worn down, neglected areas, affecting the character and pride of the community. Some of these areas are subject for development in Hawaii's TOD plans. However, it may take many more years until such improvement will take shape. As an intermediate solution, this pilot recycling facility may have the potential to support and engage communities to take matters into their own hand in neighborhood revitalization, instead of waiting till government can attain the funds.

3.2 A Hybrid Solution

Although challenges for this project seem monumental, we can focus on smaller-type interventions that could lead to significant, long-term solutions. For such a feat, not one single answer is enough, but rather a hybrid approach that could multiply the efficiency of our design intervention. This project aims to seek alternative, low-cost, and practical methods that recycle and process wood pallet wastes, and how a decentralized system can be more efficient.

Tactical Urbanism

To provide guidelines for how Hawaii communities can be participants in our wood pallet waste diversion effort, we can turn to popular trends such as tactical urbanism for precedence. Tactical urbanism uses transient, low-cost, scalable designs to approach neighborhood building and activation.[28] In figure 16, a tactical urbanism project can be run by any number of parties, ideally in harmony with one another. The bottom-up approach allows citizens to initiate immediate reclamation, redesign, or reprogramming of public space. This provides developers or entrepreneurs insight on potential designs for their market. Pairing the principles of tactical urbanism with our pilot recycling facility mission, it could theoretically become a resource for support community projects. This hybrid approach can both address our waste diversion goals as well as cultivating new community culture and identity in the process.

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[28] Lydon, Mike, and Anthony Garcia. *Tactical Urbanism: Short-term Action for Long-term Change.* 2015. 2

Figure 16. Tacticians in alternate approaches.

Source: The Street Plans Collaborative.

Low-cost and Small-Scale Design

Following the low-cost and small-scale approach to designing urban environments, the scale and program of the pilot project are narrowed to function towards niche communities. These early design drivers start to inform the scale of the recycling processing operation to fit more into a neighborhood setting. The low-cost attribute will influence the level of structural design of the actual facility. Design concepts on how these goals are accomplished are explored in Part 3 of the research where we look to precedent studies of model recycling and redemption facilities.

Conclusion

Part 1 of the research can now acknowledge that Hawai‘i continues to use incineration, landfilling, and mulching methods to recycle or divert the island's waste. For the most part, it is effective, however not sustainable. We are still using industrial-scale methods and massive amounts of energy to downcycle wood pallet wastes. The energy expended could have been better used to reclaim or retool wood pallet wastes for extended use. With insight gathered from waste composition studies and reports, we have found opportunity waste streams to provide improved diversion strategies on. This process led us to single-out the wood pallet waste streams as the primary material focus.

By establishing champion recycling, regenerative and sustainable design principles to guide the process, we can seek creative avenues to extend our target materials lifecycle. Our awareness of wood pallet waste history both locally and abroad, as well as useful attributes on wood pallet materiality, the project beings to conceptualize remanufacturing methods to create new products. Pairing with this objective with tactical urbanism design, a potential hybrid solution that’s practical, sustainable and beneficial for communities emerges. This would serve as a catalyst to influence policies that improve wood pallet recycling.

In the strive to change our perception of waste, this next chapter focuses on how waste can be remanufactured to produce valuable building products. Through case studies on waste building materials, we can formulate a processing method for how we can upcycle our focus waste material.

PART 2 | Building Material Exploration

Part 2 Building Material Exploration

Part 2 of the research is dedicated to understanding the materiality, workable qualities of the said waste product. The best practice for preliminary testing. Research here also includes an exploration of case study waste building material manufacturing processes aimed to uncovered further potential recycling methods to maximize second-life alternatives to wood pallets. The methods for material exploration includes case study research, 3-D modeling, and physical prototyping. Through this experimental phase, insight on the necessary programmatic requirements are gathered and will later serve as design drivers for defining the building scale and primary processing program.

Applying the nutrient recycling principles from Cradle-to-Cradle design, we can frame the primary direction of the regeneration wood pallet wastes. Because wall pallet wastes come in different shape, size, and condition, this framework guide how a source pallet is to be recycled. For this project, we will focus more on the technical cycle process of recovering Hawaii wood pallet waste streams.

Figure 17. Diagram of wood pallet condition and nutrient recycling option

Section 1. Wood Pallet Material Background

1.1 General Overview

This section explores the appropriate processes and methods to manufacture wood pallet waste into potential construction building materials. There is a wide range of available production processes in today's day and age, ranging from low to high-tech methods. Exploring which scale is the most applicable and cost-effective for wood pallet recycling will vary depending on the function of the building material design. Local availability of the waste material and also the process of collecting it will also affect their application.

Pallet Safety and Selection

Two billion pallets are used for transporting products every day. Many more pallets are lying around. It is no surprise that "do-it-yourself" craftsmen have created so many projects with pallets. But before recycling, upcycling, reusing, or repurposing wooden pallets, one must know which pallets are safe to use. Pallets can become contaminated with chemicals spilled on them during the shipping process. It is advised that if the wood pallet shows any spills on it, either oil, food or unknown substances, it is not to be used. Pallets are frequently used to transport dangerous or toxic chemicals/liquids. It is much safer to use only clean ones and not try to identify what might be on a wood pallet.[29]

[29] Boulze, Dimitri, Quentin Jeandel, and Heather Stiletto. *Wood Pallet: Is it Safe For Reuse For My Next DIY Project?* 2018

Figure 18. Design specs for stringer class wood pallet

Source: National Wooden Pallet & Container Association

For this project, the subject pallet design to be explored further is the stringer-class wood pallet. Being the most common pallet, it will serve as the basis for wood pallet waste building material for the rest of this research.

Treatment Stamps

Once a clean pallet is sourced, the next step is to check for a stamp or marking on the sides of the pallet. Pallets are usually stamped with an identifier which helps to identify safe pallets from chemically-treated pallets. There are two main things to look for on the stamp, to classify whether a wood pallet is safe to use. The first sign to look for is The IPPC stamp, which is a marking on pallets that stands for the International Plant Protection Convention. IPPC marking on pallets are used for international shipping. These pallets are required to be made of a material that will not carry invasive insect species or plant diseases through different countries. IPPC standards require pallets constructed using raw wood to be treated. These pallets are treated with one of the methods listed below. Officially approved agencies supervise pallet treatment methods. A pallet may or may not be safe without the IPPC stamp.[30]

Figure 19. Typical stamp markings on international pallets.

Source: https://www.universalpallets.com/2018/01/ultimate-guide-pallet-markings/

[30] Boulze, Dimitri, Quentin Jeandel, and Heather Stiletto. *Wood Pallet: Is it Safe For Reuse For My Next DIY Project?* 2018

Figure 20. An example IPPC pallet stamp..

Source: https://www.1001pallets.com/pallet-safety/

The second sign to look for on the treatment stamp is the treatment code. Pallets are treated to eliminate insects and parasites. Any pallet that is going to travel between countries must have a treatment stamp, even if no treatments have been applied. There are a few different treatment types, some of which are no longer used in the European Union. All stamps consist of a two-letter code which indicates the type of treatment applied; there are five possible treatment stamps commonly in use: DB – Debarked, HT – Heat Treated, KD – Kiln Dried, DH – Dielectric Heated, MB – Methyl Bromide.[31]

[31] Universal Pallets. *Ultimate Guide to Pallet Markings.* 2018

Figure 21. Visual inforgraphic for pallet treatment codes and information.

Source: www.1001pallets.com

DB – Debarked. Just about all pallets are made from 'debarked wood' and all it means is that the bark of the tree has been removed from the wood used. This is done to ensure any other heat treatments can be applied efficiently to the wood.

HT – Heat Treated. This pallet has been heat-treated to eliminate parasites and insects. The wood is heated to a minimum of 56°C (60°C for hardwoods) for at least 30 minutes.

KD – Kiln Dried. These pallets have been heated in a kiln to kill off any wood pests. Kiln drying can also help to avoid warping and fungal growth. Many lumber mills now kiln dry their wood to a higher temperature so that the wood can be categorized as both kilns dried and heat treated, marked with KD-HT.

DH – Dielectric Heated

MB – Methyl Bromide. These have been treated with a highly toxic pesticide which can be necessary in certain regions of the world where there are pests that can't be eliminated by heat treatments. It is recommended that pallets with an MB stamp should not be used for any craft project, and to be disposed of properly.

Colored Pallets

Pallets usually last from four to ten years. Pallet rental companies maintain them for reuse. Colored pallets usually come from one of these firms. Colored pallets (blue pallets, brown pallets & red pallets) are controversial. Rental companies own colored pallets. They don't treat the pallets with methyl bromide. Rental pallets are sometimes used for international shipping, so there can be concerns! Some countries are fumigating all incoming pallets. Not every country is always compliant with international standards.[32]

If pallets have been painted or stained in a bright color, it usually means it belongs to a pallet rental company. The color and code on each of these pallets will tell you which rental company they belong to, here are the four most common ones:

- Red pallets: pool LPR (La Palette Rouge from Europe)
- Red pallets: pool PECO (The Pallet Exchange Company from the USA)
- Blue pallets: pool CHEP (Commonwealth Handling Equipment Pool from Australia)
- Brown pallets: pool IPP (IPP Logipal from Europe)

It is advised that if a colored pallet is within your possession, the company owning the pallet must be contacted for further advice on returning the pallet. These pallets are not available, for any project as a company owns them. Besides restriction, processing

[32] Boulze, Dimitri, Quentin Jeandel, and Heather Stiletto. *Wood Pallet: Is it Safe For Reuse For My Next DIY Project?* 2018

this pallet type for recycling may produce dangerous or toxic particles, detrimental to human health.[33]

Figure 22. Painted wood pallets

Source: https://www.1001pallets.com/pallet-safety/

To take extra precaution; utilizing a scrap pallet or part of a pallet for a project is not encouraged. Many people find pallet boards with no stamp and pick out the pieces that look particularly 'rustic.' These darker, older looking pieces may have been treated with Methyl Bromide, and it's not worth risking it. One of the most important things to remember is that when you cannot establish if the pallet you have is safe or not, do not use it. For indoor projects, unless it comes from a trusted source. However, it can be used for outdoor projects where you will not be in contact with the pallet too often and avoid growing food on or near used pallet wood.[34]

[33] Universal Pallets. *Ultimate Guide to Pallet Markings*. 2018

[34] Boulze, Dimitri, Quentin Jeandel, and Heather Stiletto. *Wood Pallet: Is it Safe For Reuse For My Next DIY Project?* 2018

Dismantling Process

Typical stringer wood pallets are made up of stringers fastened in between a layer of deck boards that run perpendicular. Prior to dismantling, it's vital to understand these layers and how they are fastened so that unfastening each piece of lumber are carefully extracted. Figure 23 illustrates the layers of components that go into composing the industrial container product.

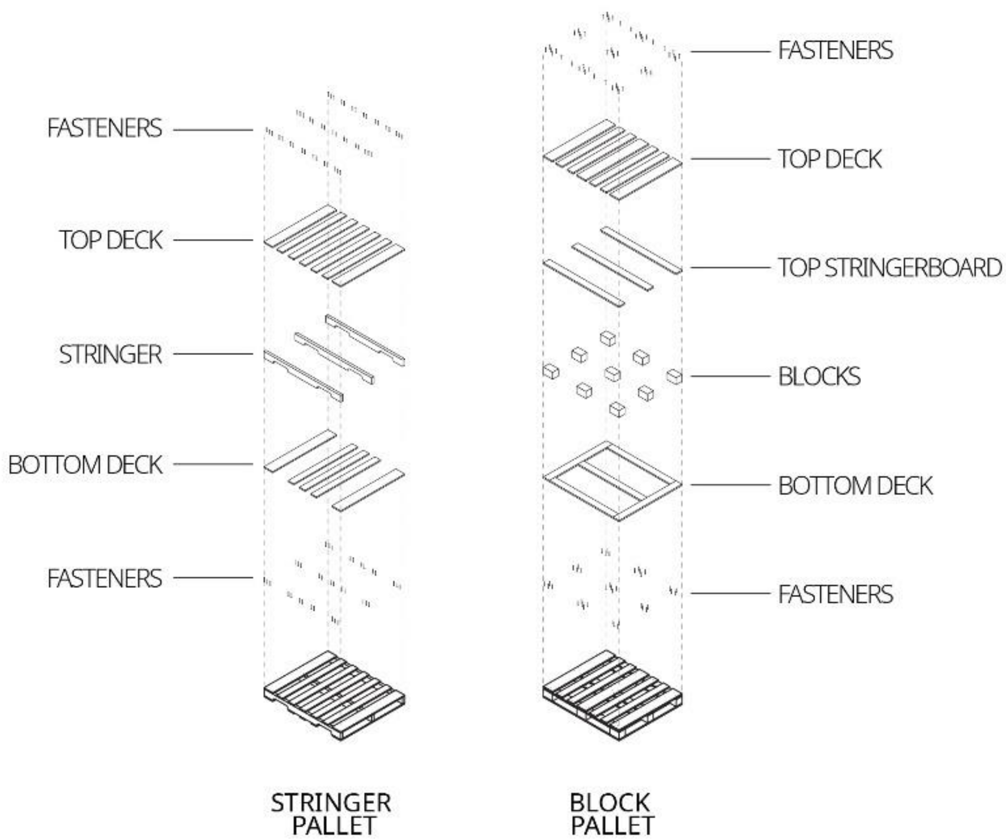

Figure 23. Exploded axonometric of the two most common wood pallets

Source: Author

There are several methods for dismantling wood pallets to strip valuable workable material from wood pallets — tools for dismantling range from hammers, pry bar, to electric-powered hacksaws. However, the fastest, cost-efficient method seems to be an industrial wood pallet pry bar. It is the most effective and efficient tool for manually stripping the deck boards from the stringers on used wooden pallets so that the timbers can be reclaimed, recycled or re-used for other purposes. It requires little practice; a standard wooden pallet can be stripped in about 2 minutes without damaging any of the timbers. The diagram below shows the simple dismantling procedure. In the last section of this chapter, a fabrication experiment will explain the use of another extraction process. This alternative method can be seen in figure 25.

Figure 24. Manual dismantling process by wood pallet pry bar.

Source: Author

Figure 25. Second extraction method

Section 2. Engineered Wood

The research inquiry leads to an exploration of available and applicable approaches to reclaiming wood/wood waste, looking to the industry and manufacturing of engineered wood products. Often called composite wood, engineered wood includes a range of wood products manufactured by either binding or fixing strands, particles, fibers, or veneers of wood through adhesives. These products are designed and engineered to specific specifications that meet certain standards. They are used in many applications such as lightweight wood framing for residential projects to industrial products. Some products can be used for joists and beams that replace the use of steel in building projects

2.1 Engineered wood products

The types of wood used for engineered wood products are made from the same hardwoods and softwoods used to manufacture lumber. Sawmill scraps and other wood waste can be used for engineered wood composed of wood particles or fibers. The production processes prove that engineered wood manufacturing has the potential to an alternative for pallet wood waste.

The types of products are numerous:

- Plywood
- Densified Wood
- Fiberboard
- Particle Board
- Oriented Strand Board
- Laminated Timber
- Laminated Veneer
- Cross Laminated Timber
- Parallel Strand Lumber
- Finger Joint Boards
- Beams
- I-Joists
- Trusses
- Wood composites

Advantages

The advantage of manufactured engineered wood is that they can be designed to meet application-specific performance requirements. They are versatile and can be made to fit a range of sizes and grades. They are designed to maximize the woods material strength and characteristics, making these products very stable and some having greater structural strength than typical wood building materials.

2.2 Applicable engineering processes for pallet recycling

Cross-Laminated Timber

The Engineered Wood Association defines Cross-laminated timber (CLT) as a large-scale, prefabricated, solid engineered wood panel. Lightweight yet very strong, with superior acoustic, fire, seismic, and thermal performance, CLT is also fast and easy to install, generating almost no waste onsite. CLT offers design flexibility and low environmental impacts. For these reasons, cross-laminated timber is proving to be a highly advantageous alternative to conventional materials like concrete, masonry, or steel, especially in multi-family and commercial construction.[35]

A CLT panel consists of several layers of kiln-dried lumber boards stacked in alternating directions, bonded with structural adhesives, and pressed to form a solid, straight, rectangular panel. CLT panels consist of an odd number of layers (usually, three to seven,) and may be sanded or prefinished before shipping. While at the mill, CLT panels are cut to size, including door and window openings, with state-of-the-art CNC (Computer Numerical Controlled) routers, capable of making complex cuts with high

[35] APA - The Engineered Wood Association. *Cross-Laminated Timber*. 2016

precision. Finished CLT panels are exceptionally stiff, durable, and stable, handling load transfer on all sides.[36]

Typical applications for CLT are long spans in walls, floors, and roofs. CLT Sizing Finished panels are typically 2 to 10 feet wide, with lengths up to 60 feet and thickness up to 20 inches. CLT widths can be manufactured up to 18 feet and lengths up to 98 feet, however, they are possible but uncommon.[37]

Glue-Laminated Timber

The Engineered Wood Association defines Glued laminated timber, or glulam, as a highly innovative construction material. Pound for pound, glulam is stronger than steel and has greater strength and stiffness than comparably sized dimensional lumber. Increased design values, improved product performance, and cost competitiveness make glulam the superior choice for projects from simple beams and headers in residential construction to soaring arches for domed roofs spanning more than 500 feet.[38]

Glulam is a stress-rated engineered wood beam composed of wood laminations, or "lams," that are bonded together with durable, moisture-resistant adhesives. The grain of the laminations runs parallel with the length of the member. Glulam is versatile, ranging from simple, straight beams to complex, curved elements. Glulam is available in both custom and stock sizes and one of four appearance classifications: premium, architectural, industrial, or framing.[39]

Glulam has a reputation for being used in striking, exposed applications such as vaulted ceilings and other designs with soaring open spaces. In homes, churches,

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[36] APA - The Engineered Wood Association. *Cross-Laminated Timber*. 2016
[37] Ibid.
[38] APA - The Engineered Wood Association. *Glulam Product Guide.* 2017
[39] Ibid.

public buildings, and other light commercial structures, glulam is often specified for its beauty as well as its strength. It's also a workhorse in common hidden applications, including simple purlins, ridge beams, garage door headers, floor beams, and large cantilevered beams. In commercial construction, glulam is used in applications ranging from large, flat roof systems to elaborate arches. Glulam also meets demanding environments of bridges, utility poles, cross arms, and marinas. Learn more about glulam in commercial and residential construction.[40]

Figure 26. Diagram of CLT and Glulam manufacturing

The obvious differences between the two engineered wood products are that CLT comprises layers of wood stacked cross-wise and bonded with structural adhesives. Common uses for CLT are for walls, floors, and roofs. Glued Laminated Timber (Glulam) is produced similarly but with the grain aligned in one direction. Glulam timber is predominantly used in structural applications, taking in the form of dimensional lumber products such as beams, columns, and joists.

[40] APA - The Engineered Wood Association. *Glulam Product Guide.* 2017

Section 3. Building with Waste

Adopting the same categorization of methods and procedures of processing waste from *Building from Waste: Recovered Materials in Architecture and Construction,* the exploration of potentially new wood pallet recycling are organized through five methods: Densified, Reconfigured, Transformed, Designed, and Cultivated. This unique cataloging system will unveil the hidden potentials of material from wood pallet waste for future building products and application.

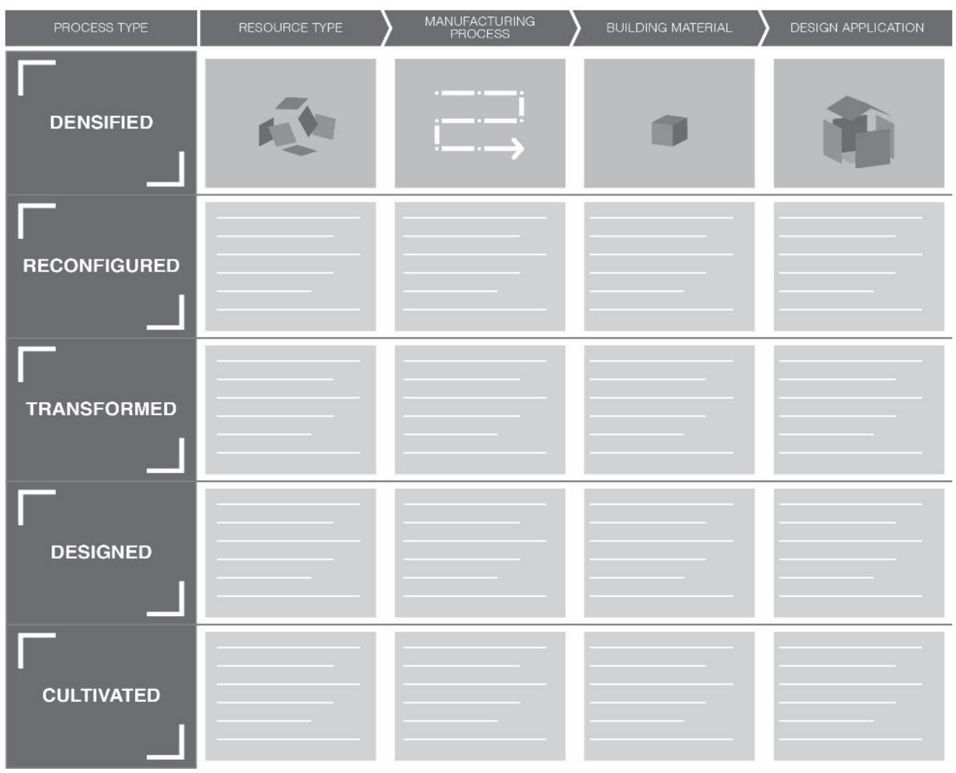

Figure 27. General framework for waste building material research.

3.1 Densified waste building materials

Densification is the typical by-product of a compression process. The critical aspect of this type of operation is that the product is 100% its material composition, without any additives like chemical adhesives. A benefit from a densified product is that it can be recycled again or reshaped, without harmful environmental effects. There are several processes and manufactured products that come out from a densification process.[41] The general method includes the great use of industrial machinery that would chip down, separate nails, and compress wood into products like pellets or briquettes used for kindling.

Case Study #1 | Stropoly Compressed Straw Panels

Figure 28. Compressed Straw Panels being used for structural framing

Source: STROPOLY®TEC

The top left photo is highly compressed straw boards are the primary building material for this single-family house in Switzerland. The densification of the raw material determines the performance of the panels. Two 40-mm highly compressed straw-fiber

[41] Hebel, Dirk E, Marta H Wisniewska, and Felix Heisel. *Building from Waste: Recovered Materials in Architecture and Construction.* 2014. 33-34.

slabs, with a lightweight panel, sandwiched in between, form a load-bearing wall as well as insulation.[42] These are building material products manufactured in Güstrow, Germany by STROPOLY®TEC. The production of STROPOLY®TEC opens new environmentally sustainable alternatives to use rice straw especially in tropical and sub-tropical areas where rice straw is available in huge amounts and where it is very often still usual to burn the straw on the field.[43]

Figure 29. Various sizes of densified straw waste boards

Source: Stropoly TEC

[42] Hebel, Dirk E, et al. Building *from Waste: Recovered Materials in Architecture and Construction.* 2014. 52-53

[43] Stropoly TEC. *StropoloyTEC Innovation*. 2018

Densified Wood Pallet Waste Concept | Particle Board

Production process for densified wood pallet waste

1 Discarded wood pallet
2 Industrial wood pallet shredder
3 Wood fibers
4 Magnetic nail separator
5 Heat compression
6 Densified wood fiber panel
7 Panels are cut to design specification
8 Batt insulation application or Particle board for furniture

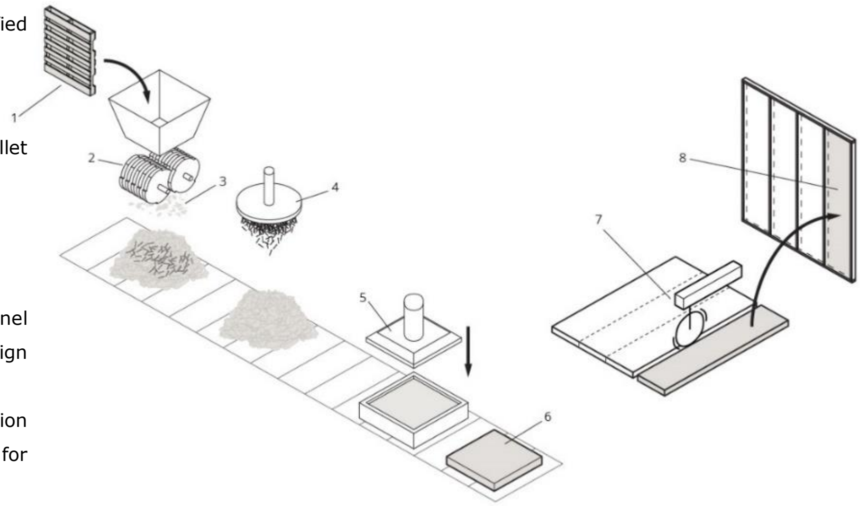

Figure 30. Production process for densified wood pallet waste

Source: Author

The concept for densified wood waste is nothing new. Recent products such as Recycled Densified Fuel or RDF products for short are energy sources for heating systems produced out of recycled sawdust, woodchips, and paper wastes. Discussed earlier on the end-of-life disposition of wood pallets; mulching is one of the leading recycling options today but considered as a form of downcycling as well.

The advantage of this type of recycling is that there is already an industry, as well as the demand for this type of products. There is already available industrial machinery designed for shredding wood pallets to manufacture products such as pellet fuels for burning. In this project, however, it looks to adopt similar processes but to form the end-product to be used for a more valuable intent. The downside to this process overall is the use of heavy machinery, which can be valid depending on the volume of wood pallet waste streams that exist in a region.

3.2 Reconfigured waste building materials

Building from Waste defines reconfigured waste materials where components of raw waste are rearranged and processed into a new construction element. Methods include shredding, chipping, breaking, or sawing of waste material that is then treated further by mixing with adhesives and shaped into form and size. Reconfiguration allows to manipulate and control the quality of the product and be designed to fit a specific building function. This method could allow for an opportunity to turn undesired wood pallet waste material into load-bearing building materials.[44]

Case Study #2 | ReMaterial's Mod-Roof

Figure 31. Alternative roofing material and detail drawing

ReMaterial is a recycling company based in India that specializes in serving developing countries with better living conditions. Their innovated product *"Modroof"* was created to solve the problem of poor roofing in slum housing with a superior roofing panel. It aims to substitute inefficient roofing materials such as corrugated concrete and sheet metal. *ModRoof* is a modular roofing system produced out of shredded cardboard, reconfigured with water, cold-compressed into molds, and waterproofed with paint.

[44] Hebel, Dirk E, et al. 63-64.

Reconfigured Wood Pallet Waste Concept 1 | CLT panels

CLT Production Process for Wood Pallet Waste

1 Extracting deck boards from wood pallet
2 Lumber parts are planned
3 Deck boards are aligned
4 Cut
5 Left over pieces can be used for glulam manufacturing
6 Three layers of deck board cuts are laid, glued and pressed
7 Offset mid-layer for tongue and groove connection
8 CLT panel unit
9 Tongue and groove edges
10 Floor assembly concept constructed by interconnecting

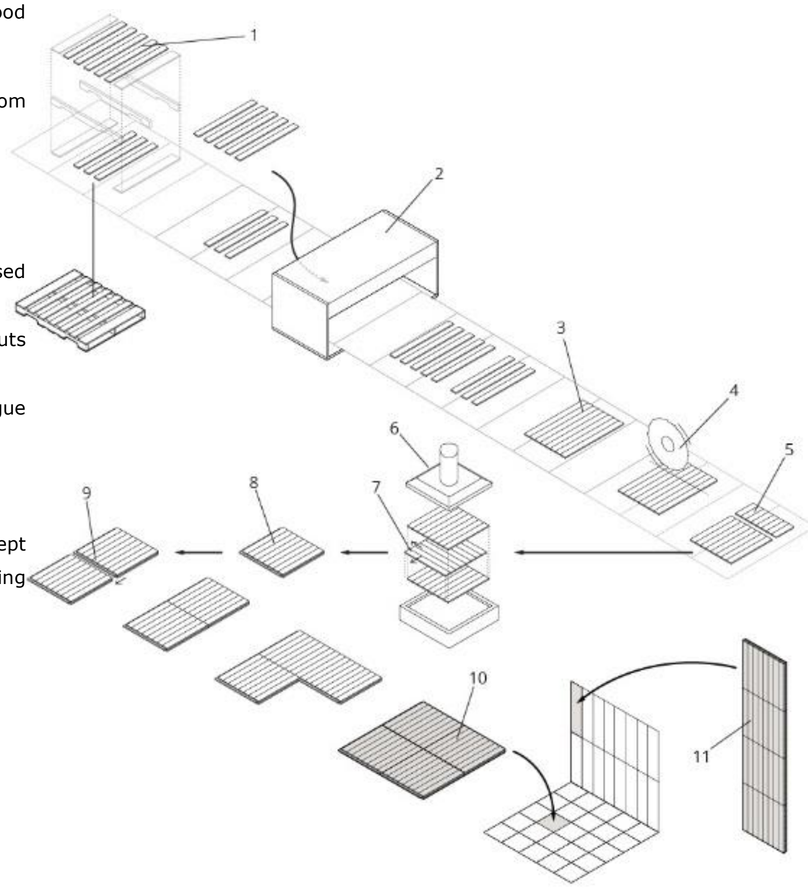

Figure 32. Wood pallet waste CLT fabrication process

Source: Author

The concept for reconfigured wood pallet waste materials leverages off of modern engineered wood manufacturing methods. A rising, popular engineered wood: Cross-Laminated Timber and its manufacturing process are applied with this building material concept. Illustrated in Figure 32 is a conceptual flow diagram of wood pallet timber extraction and reconfiguration.

The main disadvantage of this method of recycling is the consumption of energy and material. It requires more wood pallets to create a panel unit of which covers a few square footages. At step four of this production process, deck boards are extracted and cut to ensure consistent CLT panel production and connection. However, the cutaway material is underutilized. Also depending on the level of recycling operation and available material, this process requires rather bulky and expensive machinery. As mentioned, for a recycling operation to be successful, the cost of the operation must not exceed the end value of the recycled product. This concept of reconfigured wood pallet waste has the potential for useful structural application; however, the cost of production may deem it unfeasible.

Reconfigured Wood Pallet Waste Concept 2 | Glulam Lumber

Glulam production process for wood pallet waste

1. Extracted deck boards from pallet
2. Lumber boards are graded
3. Finger-jointing Deck boards finger-jointed with adhesive
4. Adhesive applied layer by layer
5. Multiple layers glue-laminated on top each other
6. 14-layer glulam beam
7. Beam size: 3.50" x 9.50" x 40'

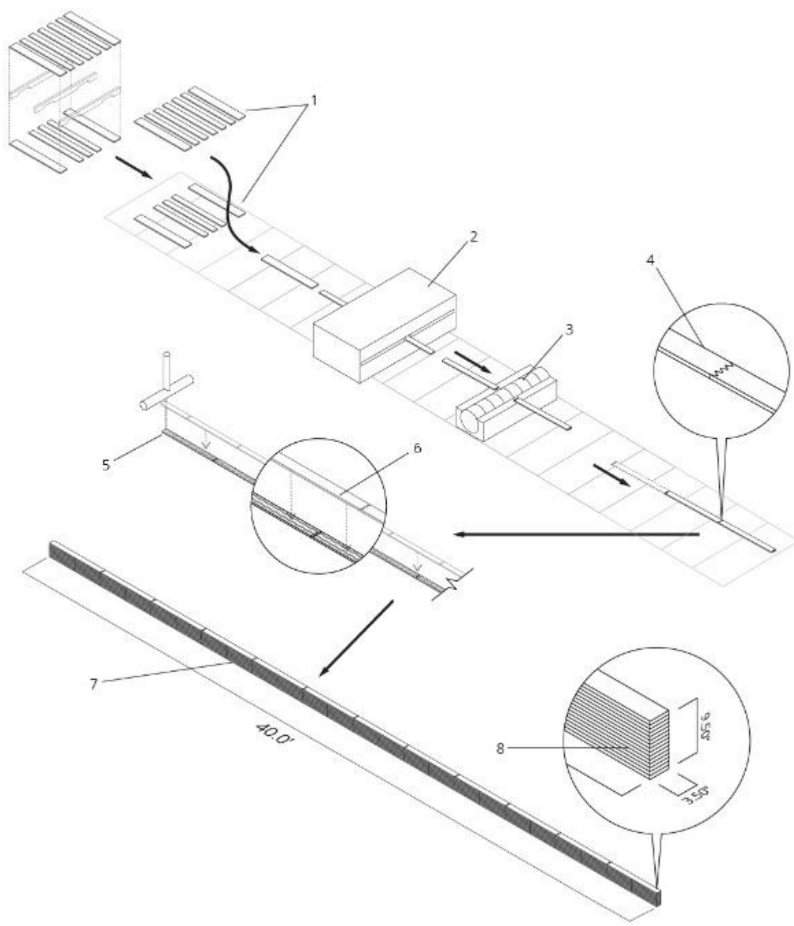

Figure 33. Wood Pallet Waste glulam lumber fabrication process

Source: Author

In comparison to the conceptual use of CLT production process for wood pallets, a Glulam process would yield a larger structural potential, utilizing as much of the pallet material as possible. Glulam seems to optimize the lengths of the lumber boards from the pallet to potentially create long-spanning, load-bearing structural systems. Adapting glulam manufacturing processes for recycling wood pallet waste is far more versatile, as finger-jointing allows salvaging lumbers that have odd or irregular lengths to be integrated into a glulam timber.

Reconfigured Wood Pallet Waste Concept 3 | Glulam Blocks

Glulam Wood Blocks Production Process:

1. Pallet deckboard extraction
2. Lumber is joined and planed working dimensions
3. Boards are finger-jointed
4. Boards glued to create longer lumber piece
5. Finished reclaimed wood lumber at 12' length x 1/2" thick x 3" depth
6. Seven finger-jointed lumber pieces laminated with interval offset boards to create tongue and groove connection
7. Finished laminated glulam beam with tongue and groove connection
8. Optional design option: Lumber is cut to a nominal 1'-0" dimension to produce wood building blocks
9. Final Glulam Wood Block and concept interlocking stack assembly

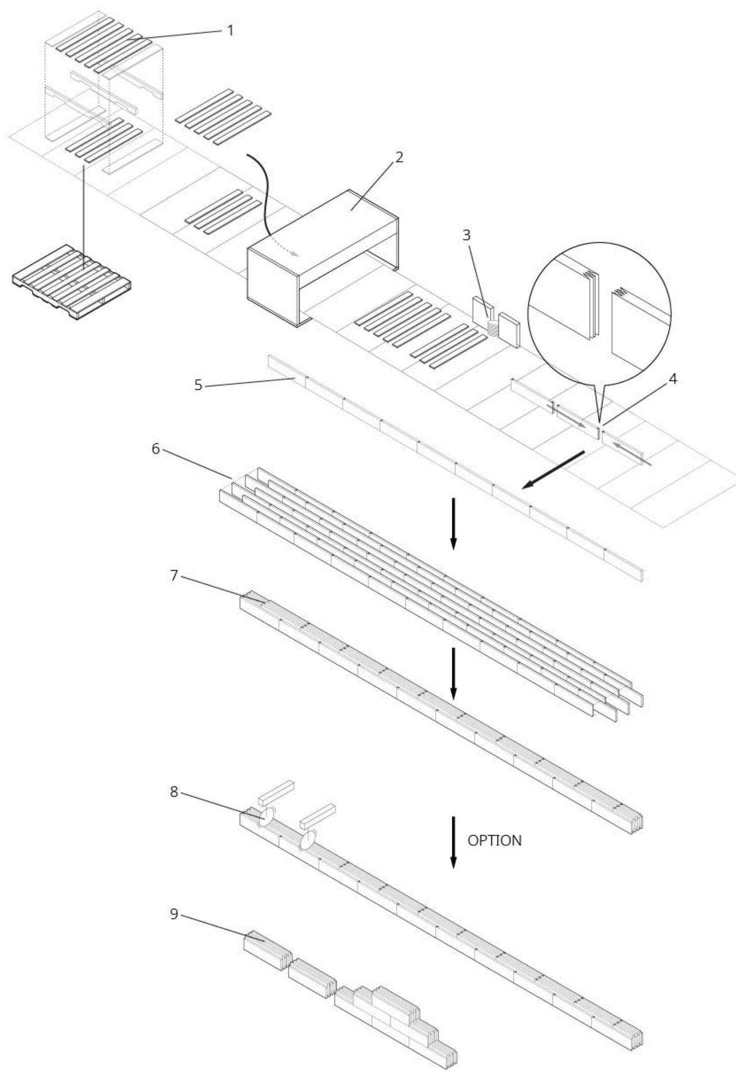

Figure 34. Fabrication process for load-bearing Glulam Wood Block concept

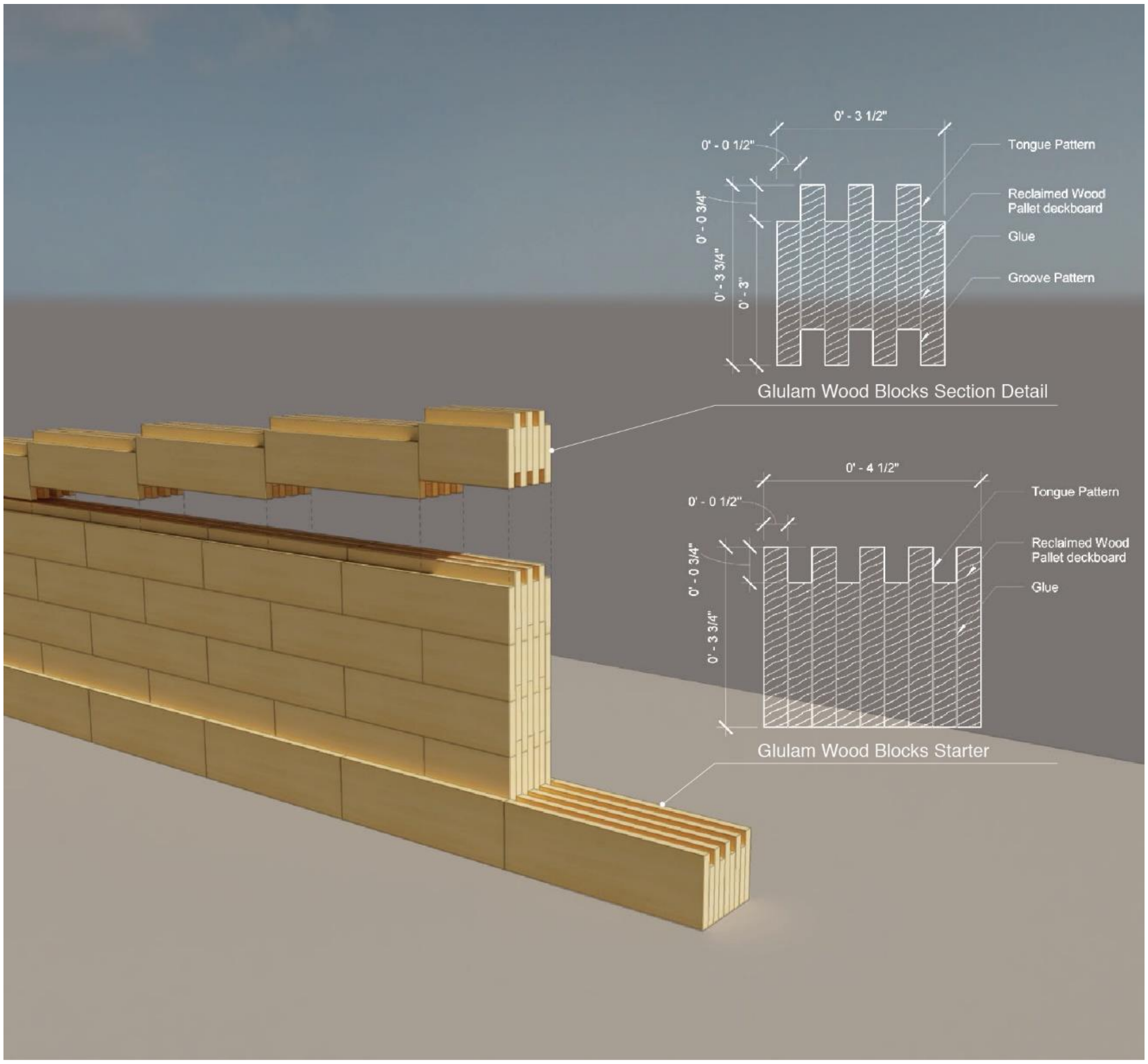

Figure 35. Wall assembly diagram using Glulam Wood Block concept

The third iteration of conceptual reconfigured wood pallet waste building material it this glulam wood blocks. The process is similar to glulam lumber fabrication, but the distinction from this product from the previous one is that the board layers in the lamination are offset to create a groove pattern for a stacking assembly design. The product can be used in load-bearing applications or create transient walls and spaces.

3.3 Transformed waste building materials

Building from Waste describes the process of Transformed Waste Materials as: "high-tech procedures that involve liquifying or gasification of the original material to create a new element with specific properties and resulting functional purposes."[45] This type of processing requires similar heavy machinery methods as densification, requiring additional energy to turn the material composition into an alternative form and workability. In this section, the transformation of the molecular state of wood from pallets is explored, the processes required to propose a new building material.

Case Study #3 | ByFusion's ByBlocks

Figure 36. Byfusion's By-Blocker manufacturing system and standard ByBlock

Source: ByFusion

Byfusion did not just create a way to transform unsorted, post-consumer plastics into unique building materials and structural assembly system, but they've also conceptualized a whole new recycling facility type that is mobile—housing the very processing system to create their ByBlocks. Reminiscent of toy bricks, an interlocking system allows for these modular blocks to be stacked and connected without the use

[45] Hebel, Dirk E, et al. 95.

of adhesive or mortar. However, steel rebars are used in practice to establish consistent assembly and lateral support.[46]

Transformed Wood Pallet Waste Concept | Composite boards

Production process for wood-plastic composite board:

1. Discarded wood pallet
2. Industrial wood pallet shredder
3. Magnetic nail separation
4. Wood fibers mixed with recycled plastic
5. Processing: Extrusion/Molding & Surface treatment
6. Use: Decking/Furniture

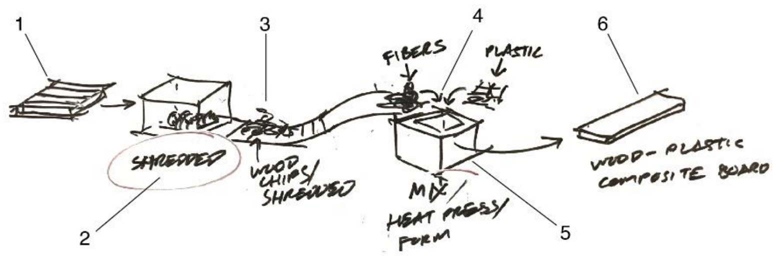

Figure 37. Concept manufacturing process for waste composite boards

3.4 Designed waste building materials

This section discusses the theoretical approach to pre-designing waste products, that when it’s original intended use is fulfilled, it evades the traditional downcycling disposition by its redesigned composition to be activated for a second-life cycle as a building material. The key aspect of this process is that the waste product remains the same, but the function and application are extended without post-production processes. Everything is designed within the pre-stages of product manufacturing to create a valuable future-based second-life strategy for the construction sector.[47]

[46] Hebel, Dirk E, et al. 114.
[47] Ibid. 141-142

Case Study #4 | United Bottle

Figure 38. United Bottle interlocking design

Source: Hebel, Dirk, et al. Building from Waste: Recovered Materials in Architecture and Construction. 2014

The design of the United Bottle is a polyethylene terephthalate (PET) water bottle, and doubles as a prefabricated building material only activated after its initial use. It aimed to advert its traditional circuit process of recycling among the 50 billion PET bottles circulating in Europe. The concept was to take it out from this recycling circuit to address an unanticipated crisis and be utilized to fulfill a need, e.g., temporary or long-term housing.[48]

Given that wood pallet adheres to stringent design and production standards, to primarily to heavy loads of product shipment, it is because this characteristic that has piqued the interest of designers, architects and craftsman's around the world to construct very creative projects to make use of discarded pallets. There are many examples in recent years of direct use of wood pallets as a building component or unit for construction. Although, as unintended as it seems, a wood pallet and pallet

[48] United Bottle Group. http://www.united-bottle.org/concept.html. Accessed October 30, 2018.

components, are in some ways designed waste building materials. With that said, explored within this section are case studies and concepts of structures utilizing whole or parts of wood pallets as building materials.

Designed Wood Pallet Waste Concept | Stacked Pallet Walls

From, decking, wall paneling, to stacking of wood pallets to create a load bearing wall, it has been proven with thousands of do-it-yourself projects by craftsman and designers around the world that wood pallets can be a valuable resource for building. Given the fact that dimensional lumber is used for manufacturing wood pallets, the concept for designed pallet waste building materials would seem unnecessary. The following idea explores applications for a wood pallet or components thereof, for building, showing how versatile this product can be.

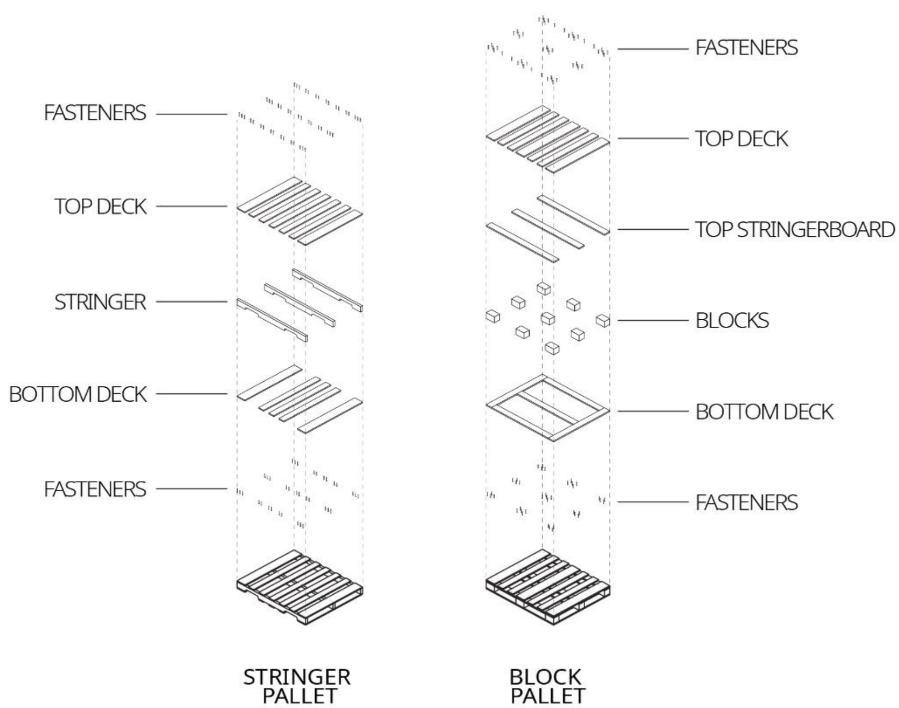

Figure 39. Exploded axonometric of wood pallet types

Source: Author

A single, whole-wood pallet can be seen as a module or unit for building construction. A simple application would be to stack wood pallets to form load-bearing walls or columns. However, the components that make up a wood pallet such as stringers and deck boards, as explored through the previous concepts, its service life can be extended. But a few direct uses from extraction could be used in floor decking, wall paneling, light wood framing. An example of this building construction typology can be seen in the Foret Pavillion in figure 42.

3.5 Cultivated waste building materials

This section explores a recent emerging building material discovery in the construction sector. “Cultivated Waste Materials” as described by *Building from Waste*, are building materials derived from a rich, self-growing resource, produced from a controlled environment, and in some cases relying on another type of waste for nutrition. The benefit from this type of process is that is versatile regarding metabolic recycling, allowing for extended life phases to be used for the next. They have quickly grown anywhere and uses minimal energy consumption. The unique aspect of this building material concept is the element of growth over time, which opens a new perspective on architecture design and construction processes.[49]

[49] Hebel, Dirk E, et al. 151-153

Case Study #5 | Ecovative Mushroom Panels

Figure 40. Ecovative's mushroom mycellium panels

Source: http://mushroomtinyhouse.com/

New York-based manufacturing company, Ecovative, use mushroom mycelium an organic matter grown and cultivated using corn stalk as nutrition. Their process includes pouring of the moist mixture molds of the desired shape. It is placed alone in a dark space where the mixture grows into the form in about 15 days. The properties of the building element can be finetuned depending on the type of mushroom and agricultural nourishment. The building element is 100% grown and compostable. They received a Class A fire rating and can take significant forces. The Tiny Mushroom, designed by Ecovative, is the first building with wall fillings grown out of mushroom mycelium material. Grown between wooden planks within a few days, the mycelium forms an airtight seal and rigid building element. The building material is cladded by sidings and aluminum panels for the roof as protection from the elements.

Cultivated Wood Pallet Waste | Mycelium Panels

Production process for cultivated wood pallet:

1. Wood pallet is processed through a shredder and nail separator
2. Wood fibers become nutrition for mushroom mycelium production
3. Mycelium can be grown in molds designed to cast building materials products
4. Panels can be used for insulation or load-bearing applications

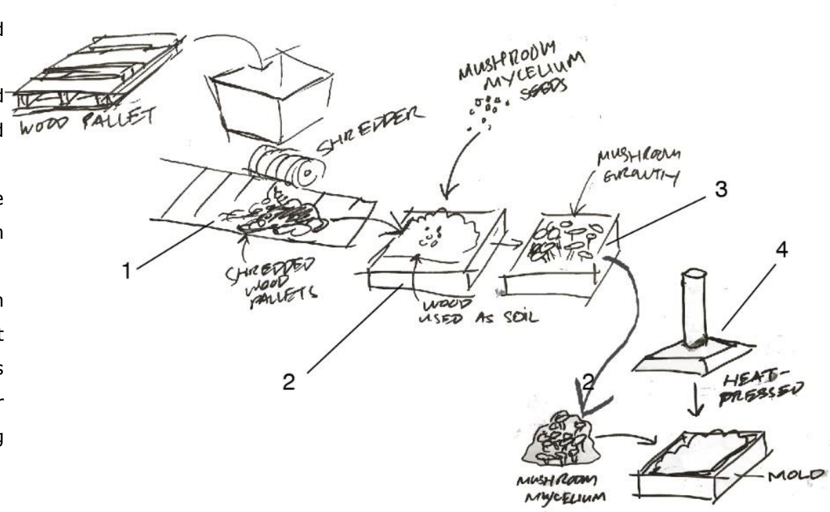

Figure 41. Concept remanufacturing process for wood-plastic composite boards

Source: Author

The working concept for cultivated wood pallet wastes follows similar manufacturing procedure as production of Evocative's mushroom mycelium building materials. However, instead of corn stalk as nutrition, the concept is to use shredded, discomposing wood pallet waste. In this case, the wood pallet waste is similar to mulching, a traditional wood pallet end-of-life disposition. However, this concept follows the Cradle-to-Cradle's biological lifecycle, using wood pallet wastes as food for the production of new materials.

3.6 Additional Examples

This section dedicates to precedent studies of actual built projects using a whole wood pallet or components of as a modular unit suggesting building tectonics. The entire pallet or parts of are used directly for a load-bearing structural application. Figure 42 displays an urban installation made entirely by stacked wood pallets. Designed by architect and teacher Justin Duchesneau and Philippe Allard, the FORÊT II (or Forest II) Pavilion is a structure built from 810 recycled shipping pallets, a cubic volume is a place for quiet meditation and reflection within the urban fabric. The light-filled temporary pavilion is made from reclaimed wood, and it represents the space taken up by a large tree.[50]

Figure 42. Forêt II Pavilion

The ETH Zurich Pavilion at the IDEAS City Festival 2015 in New York City is an example of this approach using discarded beverage cartons as its resource. Produced from paper, polyethylene, and aluminum, over 180 billion such units were consumed in the past year alone. To recycle the waste product, the laminated layers need to be separated through high water and energy use. In the United States, only about 40% of households have access to such a recycling process, sending 430,000 tons of

[50] Meinhold, Bridgette. *Inhabitat Green Design Innovation Architecture Green Building*. 2012

Figure 44. The ETH Zurich Pavilion

highly valuable material to landfills. The US company ReWall uses a method that activates this potential by pressing boards out of 100% reused, shredded beverage cartons. Although they are intended for interior wall cladding, the ETH Zurich Pavilion uses these panels as its only structural building material.[51]

Figure 43. Villa Romana Pavilion

This new pavilion located in the garden of Villa Romana, the German Institute of Culture in Florence, Italy, functions as multi-use space for exhibitions, performances, installations and other activities. The demountable structure is modular and constructed by precast diamond shaped wooden pallets and custom-made metal joints. The assembly process takes four days. The wooden structure is wrapped by a continuous PVC membrane, opaque for the roof and transparent for the walls.[52]

[51] Block Research Group. n.d. ETH Zurich Pavilion, New York City, USA, 2015.
[52] DIVISARE. 2012

Section 4. Product Feasibility Experiment Study

4.1 Sourcing the Material

Sourcing wood pallet lumber is extremely easy, if not, appreciated to be disposed of by many businesses. Yet the mode to transport the material for use remains highly dependent on accessbility to the source's location and proper vehicular hauling. Pallets sourced for this material prototyping were taken from business warehouses in Mapunapuna, Honolulu.

Figure 45. Wood pallet stacks behind local business warehouse. Mapunapuna


Figure 46. Loading pallets onto truck bed

4.2 Sample glulam lumber fabrication

This section explores the feasibility of the remanufacturing of wood pallet lumber waste into structural building material. Glulam lumber was chosen to be the product to be fabricated in this experimental study. By undergoing the actual process curated in the previous section, this hands-on experience aims to uncover qualitative aspects and constraints to such operation. Observations from this physical study will reveal insight into the facility design, which would impact the scale, workflow, spatial organization of essential equipment. This entire fabrication study was accomplished at the UH School of Architecture Fabrication Lab.

The chosen product and fabrication processes will dictate main drivers for program, style, and type of intervention. Within this aspect, to tie the research and design together, the waste building product explored would also appear within the design of the physical structure of the facility. This utilization of the selected wood pallet waste building material within the design proposal showcases its direct application for the construction of spaces.

Dismantling Process

There are multiple ways to extract reusable lumber from a pallet unit. Industrial tools such as a pallet pry bar allows for greater yield on deck board extraction from a single pallet as it carefully pries off and dismantles a pallet with minimal damage to lumber. However, nails that are still attached unto the deck board after extract becomes one of the arduous processes of dismantling. The removal of all nails or fasteners off each extracted deck board would be the next step when utilizing this method, as depicted in figure 49.

Figure 47. Wood pallet lumber extraction

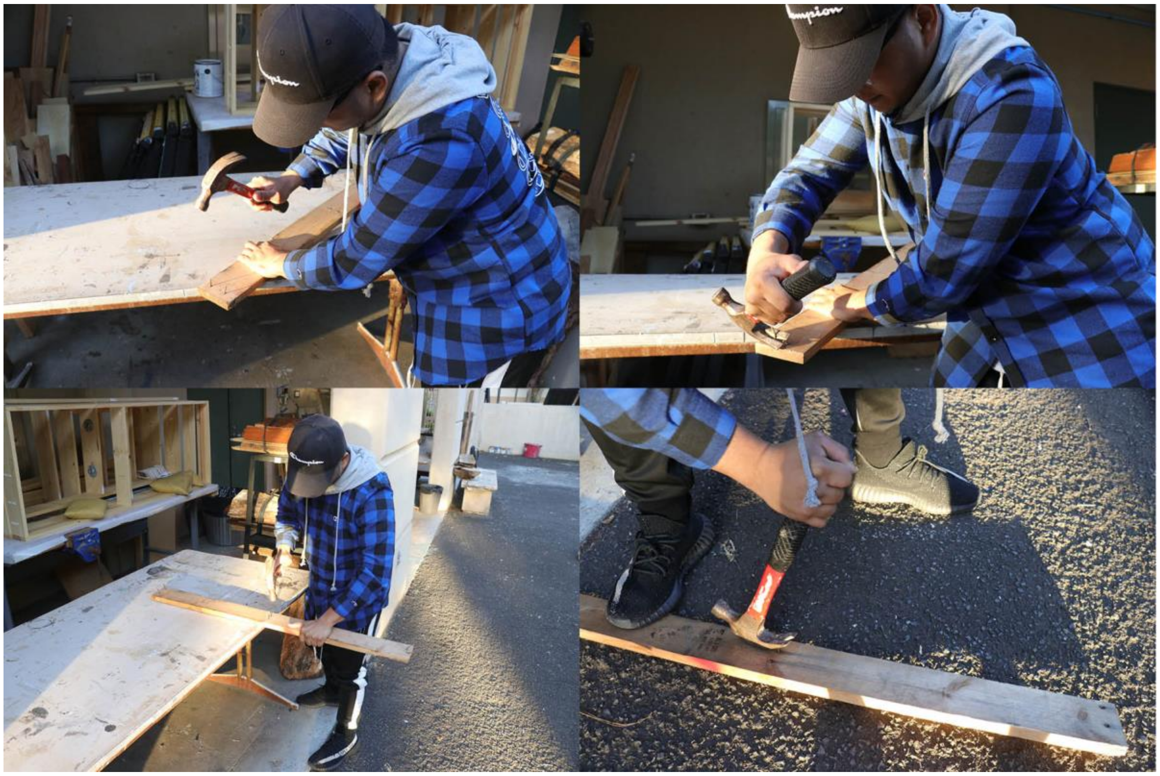

Figure 49. Removing pallet fasteners

Figure 49. Extracted pallet lumber

Recycling Off-Cuts

Prior to milling each lumber piece into working dimensions after removing all nails, portions of the deck board where once the fasteners were nailed in are cut away. (figure 50). Although the nails were removed earlier in the dismantling phase, this best practice adds an extra layer of protection to avoid damages to shop equipment and the worker, should there be any remaining metals hidden in the lumber piece.

Figure 50. Removing nailed wood areas

Since this is a necessary step, an alternate method for extracting lumber from a wood pallet would use a circular saw and directly cut out the deck boards away from the stringers they are fastened onto. Figure 51 shows the detached lumber pieces to be utilized. This method is much quicker; however, it requires proper handling of the tool. Another observation from going through this process is the realization of unworkable wood pieces that were a by-product of the lumber extraction. Because the glulam fabrication process requires more uniform working lumber, "off-cuts" or leftover wood pieces (figure 52) can't be used in this particular remanufacturing process.

Figure 51. Alternative lumber extraction method

Figure 52. Wood pallet offcuts

While maintaining the "nothing goes to waste," mindset, a viable solution for these off-cut pieces, as well as wood chips, sawdust, and other irregular wood pieces would then defer towards the biological cycling principle of Cradle-to-Cradle design. Because most of the sourced wood pallets are only heat-treated (not chemically), it can be transported to the existing mulching facilities such as Hawaiian Earth Recycling, as viable, last resort to divert the material from being incinerated and/or landfilled. Collection for this recyclable material is explored in the schematic design phase of this project.

Losing portion of the pallet deck boards lessens the linear footage of the lumber piece which creates an irregularity in length as well as a workflow in the glulam lumber fabrication process. Early on the reconfigured wood pallet waste conceptualization, the whole wood pallet deck board was the dimensioned metric for building and layering a large glulam beam or CLT panel. This fabrication study thus displays the reality that such ideal, uniform manufacturing requires further steps and alterations.

Lumber Milling

That process begins with joining, which is accomplished through a jointer machine, (figure 53). The last step in the material milling process is running the joined deck board through a thickness planer to flattening/straighten the remaining side of the lumber board, but more importantly, bring it to the desired dimension (figure 54).

Figure 53. Milling deck board face and edge through a jointer

Figure 54. Lumber is planed down to a desired thickness dimension

Finger Joining Process

An essential step in the fabrication process is connecting the refurbished board pieces together to create longer pieces of lumber for lamination. The low-cost method to accomplish this was to utilize a router with finger-joint bit. Combined into the cross-cut table saw shown in figure 55, is the jig setup for the router station. A custom fence was made for this particular process to provide safe and efficient workflow. Along with this setup was the use of a coping sled shown in figure 56, where lumber pieces are clamped into to create finger-joint grooves by sliding the sled across and against the fence pass the router. To create the "Side-B" groove of the board to connect to the next, a piece of 1/16" piece of wood was used to elevate the board to offset the groove pattern, resulting in a finger joint connection, as depicted in figure 57.

The length of a single finger-joined board can be limitless, making it possible to fabricate a variety of customized lengths of glulam lumber. This process alone can already produce building construction materials because it creates dimensional pieces of lumber. The boards in figure 57 were about three inches wide and about one inch thick, so theoretically this process of finger-joining boards can be milled to produce more products such as wood slats, purlins, lattices, moldings, panels, all of which utilize more or less the same dimensions.

The major drawback of this process is that it requires constant height adjustments of the router bit. This is due to the irregular sizes of deck board thickness extracted from different sourced wood pallets, which can cause inconsistent uniformity of board layer thicknesses within the glulam lumber, leading to affect the structural integrity of the final product. A direct solution may be to mill every extracted lumber down to fixed thickness, thus solidifying this fabrication procedure.

Figure 55. Finger jointing jig and router setup

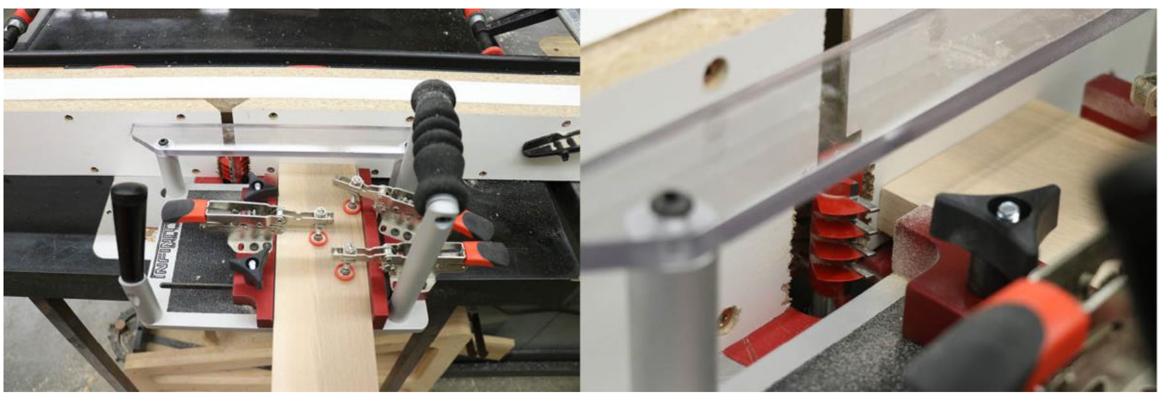

Figure 56. Wood pallet deck board clamped into coping sled for finger joint routing

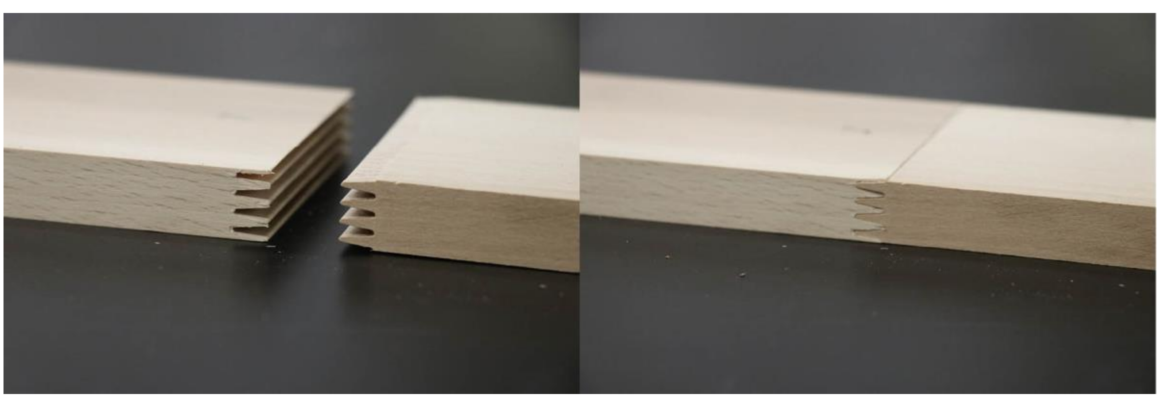

Figure 57. Sample finger joint connection

Lamination Process

The last step in this fabrication experiment is the gluing or lamination of the lumber boards. Fast-drying *Titebond* wood glue and clamps were used during this step, making the sample piece to cure in a few hours (figure 58). However, it is recommended a minimum of 24 hours for stress joint portions. Considering that termites are a prevalent problem in Hawai'i, an extra layer of protection can be added to the product by possibly using an alternative termite-resistant adhesive for lamination. Once the lamination has cured, the product is milled again to remove any imperfections (figure 59. The finished glulam beam or post seen in figure 55 is only a test to understand the rigors of the labor process in fabrication using very minimal equipment. Theoretically, the length the product can be longer, and sized to fulfill a specific structural or non-structural need.

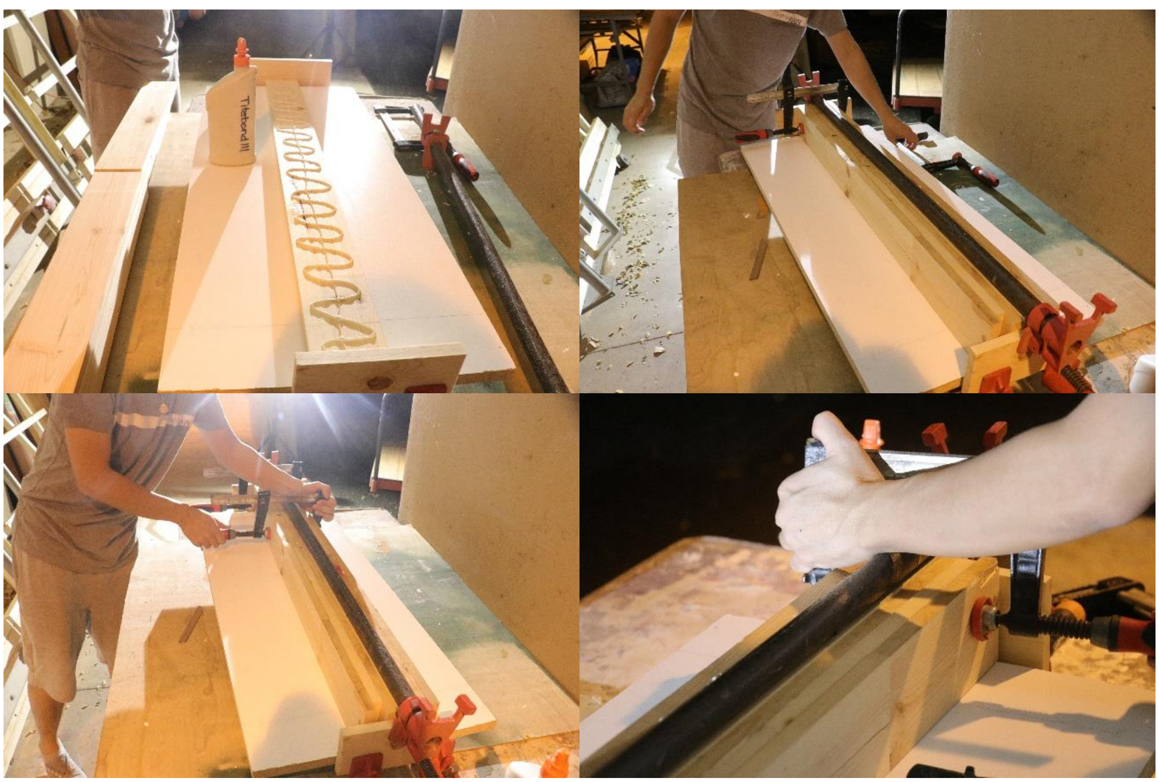

Figure 58. Laminating reclaimed wood pallet lumber

Figure 59. Post lamination milling

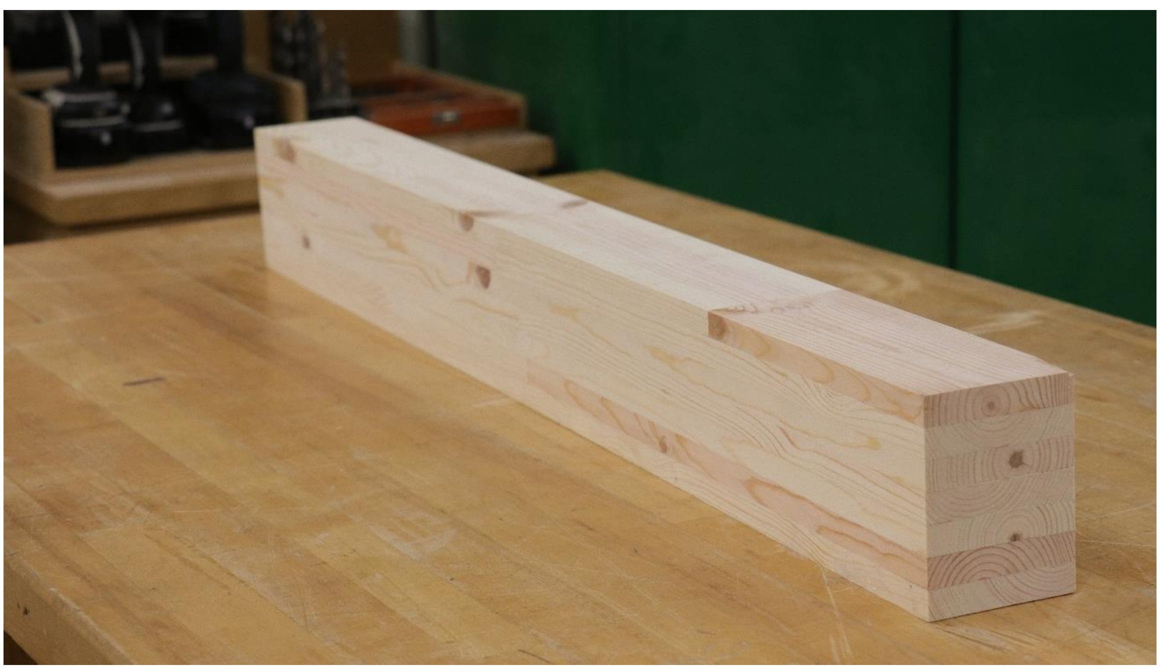

Figure 60. Finished glulam lumber sample

Conclusion

For an operation like processing waste to building materials to succeed, the cost for such operation should not exceed the value of the product or cost more than conventional imported materials. This project argues that there are processes that are inexpensive, creating valuable products for construction, saving on materials spending. On the ecological and environmental side, the added benefits through the building from waste allow for fewer greenhouse emissions by diverting from contemporary waste management systems, and the exploitation of natural resources.

Ideally, the next step would be to run structural tests and simulations on said building products against standard, dimensional lumber. This is would be a new layer of research to conduct, and necessary for actual usage whether for personal woodworking projects to residential applications. To ensure safety, products must be tested for it to be safe for practical application.

Losing portion of the pallet deck boards lessens the linear footage of the lumber piece which creates an irregularity in length as well as the workflow in the glulam lumber fabrication process. Early on the reconfigured wood pallet waste conceptualization, the whole wood pallet deck board was the dimensioned metric for building and layering a large glulam beam or CLT panel. This fabrication study thus displays the reality that such ideal, uniform manufacturing requires further steps and alterations.

PART 3 | Program Development

Part 3 Program Development

Understanding the complex recycling and fabrication operation behind creating a waste building product provides great insight on key spatial requirements, equipment, and processes that will have a critical impact on the function and form of the very building structure it is being made in. The recycling or fabrication methods that show feasibility will carry on to the next phase of programming research for a new recycling facility for Hawaii’s wood pallet waste. This next portion focuses on exploring the wide range of waste management practices and systems that go beyond just recycling. This is important because the design will become a hybrid intervention, one that is versatile and could address the problem in a creative way. We turn to precedent recycling facilities locally and abroad to discover strategies for our facility and program design. Ultimately, it will inform spatial and programmatic constraints on our pilot design.

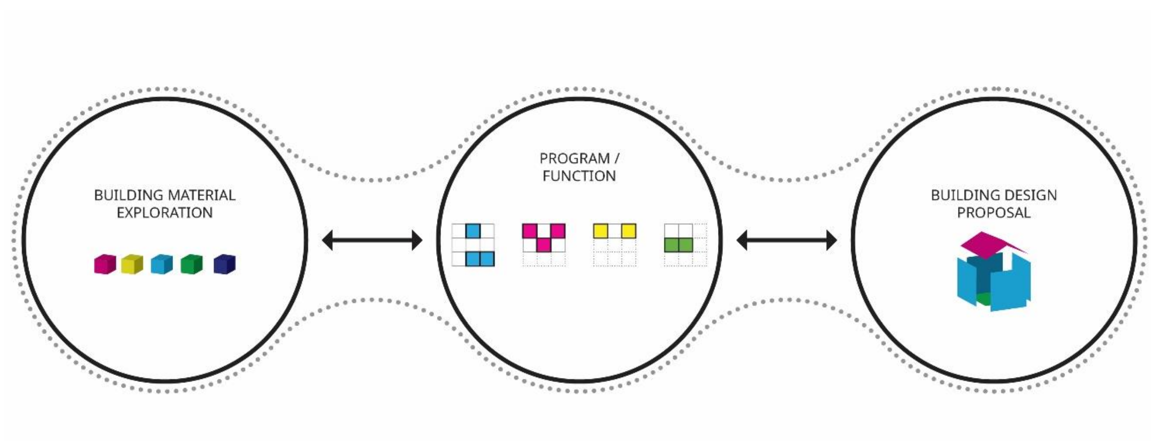

Figure 61. Research process diagram

Section 1. Precedent Studies

To gain a better picture of how an ideal recycling facility would look like, we turn to precedent examples of existing facilities that showcase inherent qualities, aspects of design that would later inform the approach for final concept design. Much of the program in these precedents lend themselves to the site they are located in, the community that they serve, and the type of materials they collect. Scale is a very important factor in any building design but it is also influenced by the function of the program.

1.1 Local Hawaii Collectors & Recycling Companies

It’s important that before proposing a new program or facility type, an exploration of what facilities related to the project’s missions exist locally and abroad. Understanding what is currently being done in Hawai’i in efforts to wood waste recycling and waste building materials, to uncover areas we a new program proposal may help improve our collective strive for better resource efficiency for Honolulu.

There are many local companies on the island of Oahu that provide a variety of recycling and collection services. The City and County describe “collection” as the hauling and storing of recyclable material from homes or businesses, which then gets delivered it to a recycling company for actual processing. For example, companies that recycle paper, glass, and metal, their "process" would include compacting, baling, crushing and either shipping off-island or delivering to a local end-user. For companies that compost a recyclable material the word, "process" means that they are creating the new product onsite, i.e., Hawaiian Earth Products. [53]

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[53] "Collectors & Recycling Companies." How the City Manages Our Waste:: City & County of Honolulu, Department of Environmental Services. Accessed February 23, 2019. http://www.opala.org/solid_waste/archive/Collectors_and_Companies.html.

Convenience Centers

There are nine public waste collection points in the city and in Honolulu County: six convenience centers and three transfer stations across the island that allow residents to dispose of their household waste. Residents can use these places for free. These centralized locations service the town or city it is located in, but it also becomes apparent that wood and wood pallet wastes often find its way here. These facilities collect refuse and construction and demolition waste, which is then transferred to H-Power for incineration. Often times that is the disposition for the Oahu's wood waste stream. One of the limitations in this research was to uncover the current policies local businesses have on disposal of wood pallets. Therefore, it would be inaccurate to state that all disposed wood pallets are dropped off in convenience centers such as the ones mapped in Figure 62. But according to earlier statistics discussed earlier in Part 1 on wood pallet waste tonnage received in H-Power, shows proof that the waste resource is being transferred and incinerated. Mapping out these key facilities helps provide a synthesis for how the building intervention is to be positioned to allow diversion or interception of the waste resource.

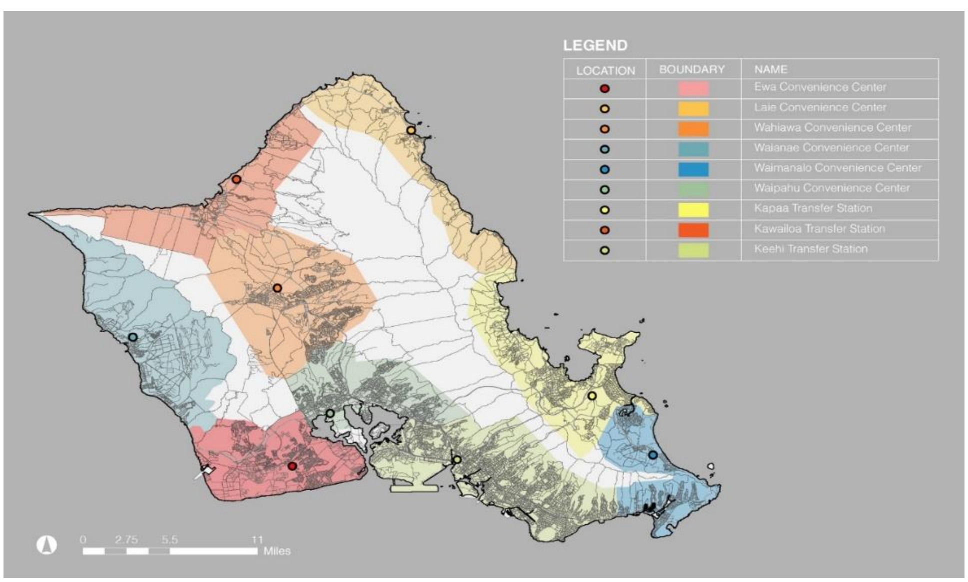


Figure 62. Locations of Convenience centers and Transfer Stations

Redemption Centers

Rather than throwing away recyclable beverage containers, Hawaii has implemented the HI-5 beverage container deposit program to aid the diversion of the material from entering our municipal landfill. A multitude of private companies has emerged to provide collection, the redemption of valid containers, some accepting multiple types of recyclable materials, and locations spread across the island of Oahu. One of them being Reynolds Recycling, one of Hawaii's largest material recyclers. Unlike the other facilities, however, Reynolds Recycling has systemized their collection system by utilizing mobile trailer bed containers, stationed in multiple locations in Hawaii, as depicted in figure 63. Their success lies in the convenience and accessibility to residential and urban mix-used zones, allowing for greater collection volume.

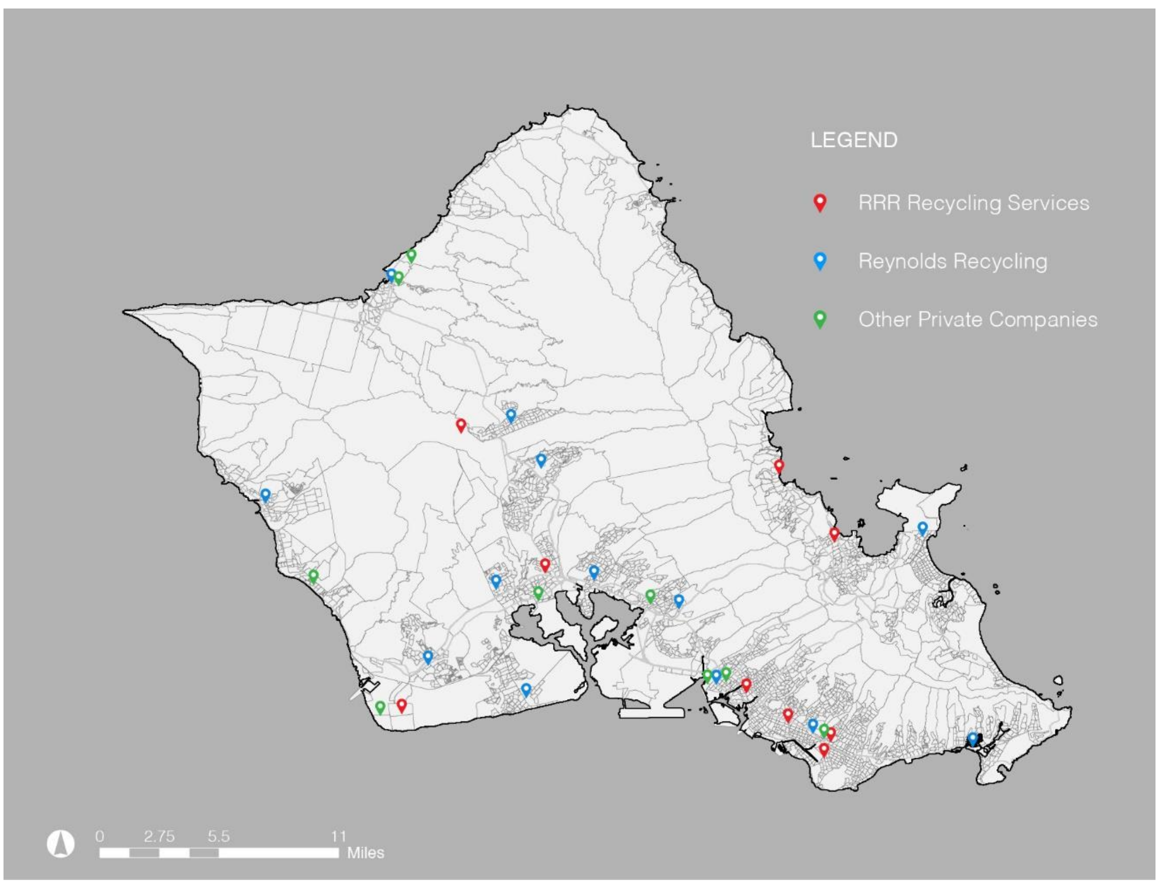


Figure 63. Location of HI-5 Redemption Centers

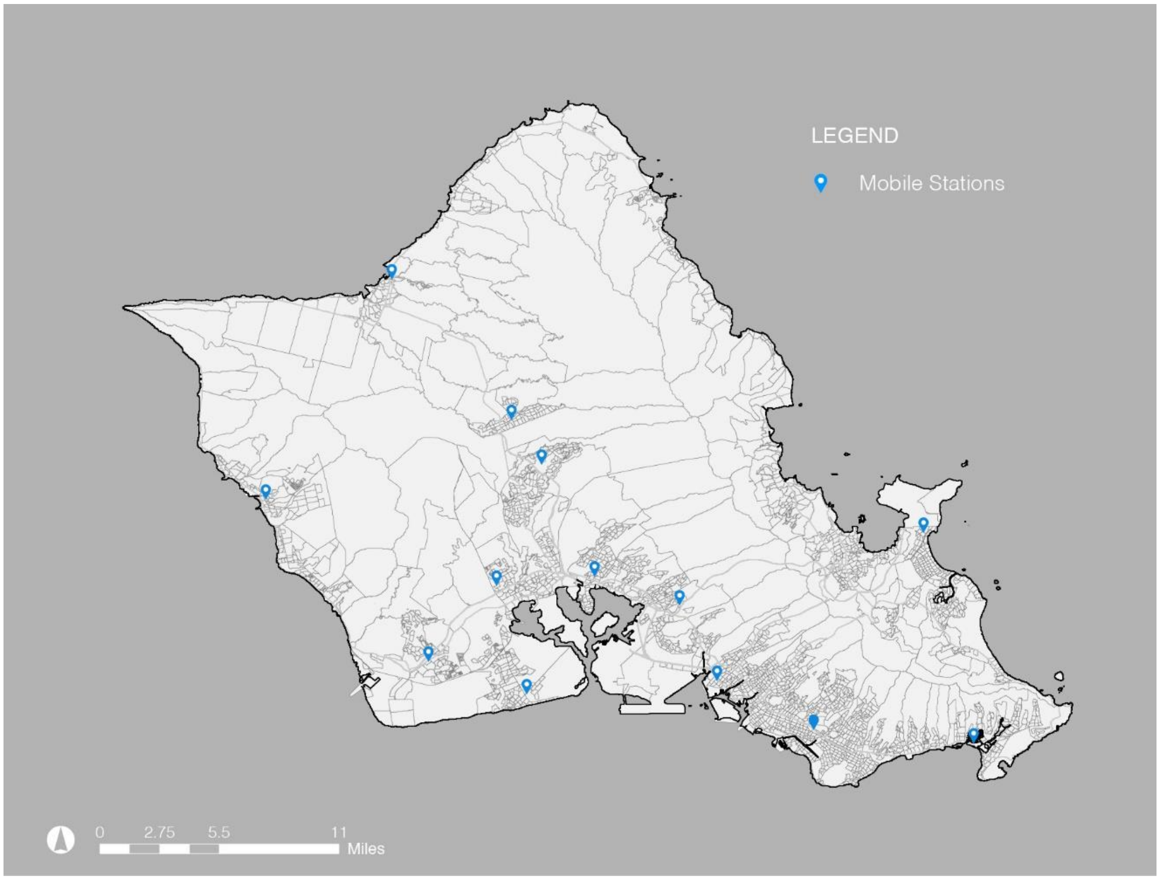


Figure 65. Network of Reynolds Recycling mobile location

Figure 64. Reynolds Recycling mobile HI-5 collector

1.2 International Precedent Facilities

Precedent Study #1 | El Cerrito Recycling Center, California

Figure 66. El Cerrito Recycling Center. California

This 2-acre design-build project designed by Noll & Tam Architects transformed a beloved neighborhood resource into a destination built around sustainability. With an average of 400 visitors a day, the circular site plan safely separates operations and visitors' paths of travel. LEED Platinum certified the center is a demonstration project for net-zero waste, restoration and regeneration, and community values. The design incorporates solar panels, rainwater cisterns, native gardens, rain gardens, and educational signages.[54]

[54] Noll & Tam Architects. El Cerrito Recycling Center.

Precedent Study #2 | Smestad Recycling Centre, Norway

Figure 67. Smestad Recycling Centre, designed by Longva arkitekter

Completed in 2015, the Smestad Recycling Centre represents a new building typology recycling operation. Longva Arkitekter designed this facility to allow the public to handle all wastes indoors. The recycling center includes a robust open hall with two distinct areas: one for the public and one for operations. The building has a saw-tooth roof that gives the large volume a subdivision and rhythm. The operation logistics was the important design criterion, making sure the plan maximizes traffic flow, parking, and maneuvering for operations. The recycling hall's back and sidewalls are predominantly closed. The main façade towards the ring road is open, clad with expanded metal sheets mounted between the columns of laminated wood.[55]

[55] Longva Arkitekter. Smestad Recycling Centre. 2016

Precedent Study #3 | Nosara Recycling and Education Center, Costa Rica

Figure 68. Recycling and Education Center in Nosara, Costa Rica.

Led by architect Tobias Holler and a small group of students of New York Institute of Technology, this service project was aimed to help alleviate a failing waste management problem in the Nosara, Costa Rica. The program focused on creating a recycling and education center run by the Nosara community. The building itself takes inspiration from local passive tropical design strategies and is a long, narrow, open-air volume to encourage natural ventilation. The center has three zones (a sorting facility, an open lobby, and support spaces) under a common roof are made from locally sourced timbers and recycled materials.[56] The building was constructed from low impact materials Facades are of concrete, brick, laminated wood and expanded metal of weathering steel. The entire roof is planted with sedum. High ceilings with reflective roofing material help minimize interior heat build-up.

[56] Holler Architecture. Nosara Recycling & Education Center.

1.3 Unconventional Typologies

Precedent Study #4 | AMP Spacecraft

Figure 69. The Agbogbloshie Makerspace Platform

Source: https://qamp.net/

Located in Agbogbloshie, Ghana, AMP spacecraft is an alternative architecture for making. Its success lies in its small, mobile, incremental, low-cost design. It houses open-source space probes that serve as toolkits to equip makers in the region to maximize their recycling and making potential. This last case study resonates much of the aspirations for this projects design approach. Design values such as low-cost, flexibility, mobility, and community engagement can be extracted from this case study project alone. Looking ahead to help with visualizing the approach for the projects final design, a matrix will be used to quantify the impact of design values garnered from all previous case studies and precedents. This will be covered in the predesign phase in Part 4.

Section 2. Setting up a Recycling Program

2.1 Mandatory Recycling Laws

The City and County of Honolulu have made the recycling of target materials a legal requirement for most companies and government agencies. The city encourages recycling of as many materials as possible but requires some materials to be recycled or composted and thus diverted from city disposal sites. The City also stated that the commercial sector has the highest potential to significantly increase recycling on Oahu. Large companies that produce large quantities of recyclable materials may also be able to reduce their disposal costs if recycling is integrated into their waste management system.

Entities Affected

There is no shortage for locating entities and businesses that generate the resource for a new wood pallet recycling facility to operate. The mandatory recycling laws set forth by the City affects commercial entities on Oahu. That would include restaurants, bars, hotels, office buildings, shopping malls, retail stores, grocery stores, hospitals, food courts, food manufacturers and processors, golf courses, parks, tree trimming, car dealers, home appliance retailers.

Almost every large business on Oahu is affected, either directly or indirectly, by the City's recycling requirement. Some of the requirements specifically identify the types of businesses that are required to set up recycling systems for targeted materials. These materials are the most common recyclables; glass, paper, food wastes. The City is very strict in the recycling of these materials that they have implemented disposal bans and restrictions on high volume recyclable materials, including green waste, carboard, tires, auto batteries white goods and scrap materials, which are enforced on disposal sites.

Wood pallet waste, on the other hand, does not have the same volume as these target materials to be subjected to the enforced mandatory recycling ordinances, but nonetheless, there is an opportunity to place better collection and recycling program for this waste stream. Stacks, piles, of wood pallets, in excellent or rooting conditions can be seen virtually everywhere especially in commercial sectors. To show the City how creative waste diversion and good architecture can come together to form an alternative urban intervention for wood pallet waste diversion, is the prime focus for the remaining parts of this project.

2.2 Guides for setting up a recycling program

The City and County provide online resources to help businesses set up recycling offers a model recycling program, peer consultants and detailed guidelines for designing recycling systems, employing waste prevention strategies, buying recycled products and educating employees. This section describes the necessary steps to developing a recycling program, as prescribed by the City and County.

There is a total of five steps designed for businesses in Hawai'i to get a sense of direction and a basic understanding of how programs are developed and put in place. (Figure 70) The City and County state that the goal for businesses is to develop a practical, cost-effective, recycling plan that results in a sustainable recycling program. With the same goals in mind, the design proposal produced in this project could serve as a concept pilot model for businesses seeking alternative disposal of their wood pallets.

Figure 70. Steps for setting up a business recycling program

Section 3. Program Framework

This design application of this project then starts to address how it fulfills some steps of setting up a recycling program. The scope of this design intervention discusses several steps in the recycling program setup, steps explicitly 4-6. Because the origin of wood pallet waste comes mainly from commercial businesses and big-box companies, the objective is to target these large entities and provide an alternative to their wood pallet recycling/disposal policies. The City and County makes minimal effort in giving alternative strategies to reclaim wood pallet wastes for business in Oahu. Following guidelines set forth by the City to set up a recycling program. The approach is to leverage off the research, design values, and concepts uncovered in the previous chapters to meet its requirements. The end design would be a proposal for a new recycling program for wood pallet recycling for local business in the State of Hawai'i.

3.1 Designing the collection system

The City and County suggest that to make sure recyclables can flow from individual employees to area collection containers or directly to central collection/storage. This is currently the case for wood pallets and the reason why they can be seen in the loading docks of large major retailers.

According to Hawaii's Department of Environmental Services, the design of a collection system may include:

- Containers and Locations
- Transferring to Central Collection and Storage Central
- Collection/Storage Area

Proposal

The concept for how the pilot project collects its wood pallet waste is not much different the general refuse and bulk-up services. Basically, the pilot recycling facility is stationed in an optimal site location within the proximity of the industrial or commercial activity, and near an urban or residential neighborhood. A collection vehicle goes door to door to business in the area to offer wood pallet waste pick up. This system can be easily implemented especially if companies to sign a contract to participate in scheduled wood pallet recycling. Figure 71 best illustrates this collection strategy.

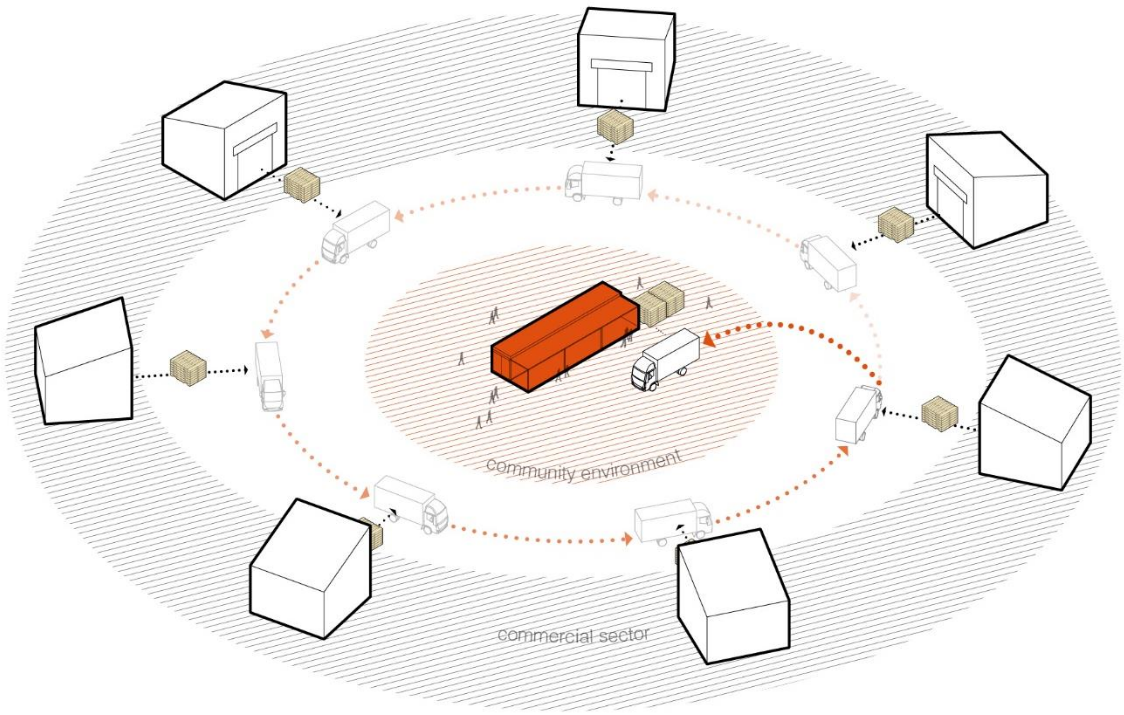


Figure 71. Collection system concept diagram for pilot recycling program design

Part of the design of this pilot facility is deciding whether it a stationed within a site or subject to a scheduled traveling to service multiple locations. Reflecting on design values that speak towards building a sense of cultivating a culture and community identity and economy, the former is more suitable than the latter. The pilot facility will be stationed on an opportunity site. However, the building design can be mobile and can be relocated to service other urban areas. For this pilot design project, the building design will look into prescribed site location that will address existing wood pallet recycling. This is covered in the following chapter.

Conclusion

Each precedent study explored in this section evoked a design value that influences either the function, form, or program of their facility. To provide a framework that informs the characteristics of the pilot facility design these design values will be gathered and evaluated graphically by their level intensity or relevancy in each of the precedents. The project will seek which values resonate more towards the design approach, to have more influence on the final building and program design. This visual framework is detailed in Part 4.

Reflecting on the earlier concept of promoting community engagement as a design value, the collection system does not have to rely on the project's main vehicular hauler. Local residents can be encouraged to source and bring their own wood/wood pallet waste to the facility to be processed, to create material for personal projects. To support this culture of recycling and making, people may learn to handle and process their own lumber, and keep what they make. By providing and equipping people with the tools to make, it can empower individuals and communities, give opportunities to produce an economy, and cultivate a sense of community identity and character, all in the realm of waste diversion.

PART 4 | Predesign

Part 4 Predesign

Section 1. Design Approach

1.1 Formulating Design Values

The research and case studies in the previous parts and sections help develop the framework for the program and design language to be used in this final design proposal. To accomplish this, design aspects or values are derived by the case study and precedent studies examined in the previous chapter.

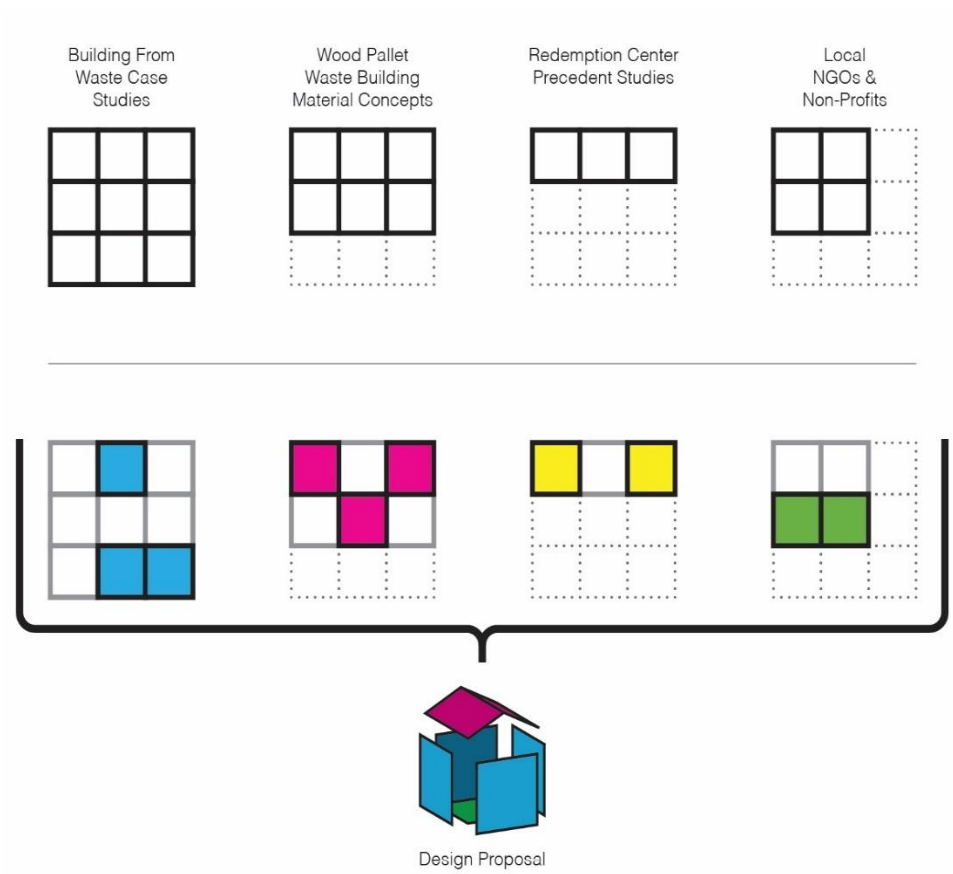
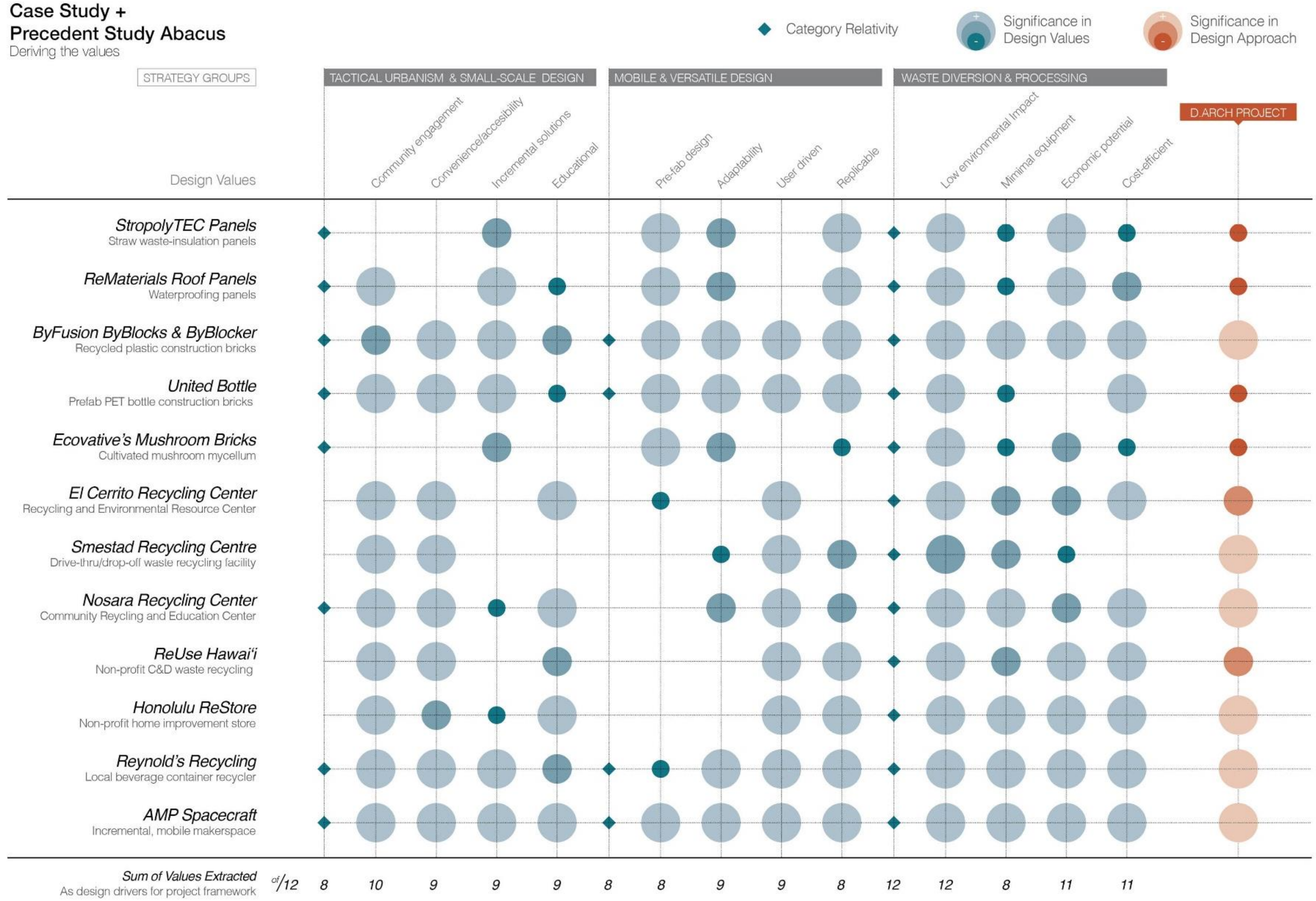


Figure 72. Illustration of extracting design values for the design proposal

Case Study + Precedent Study Abacus

Deriving the values

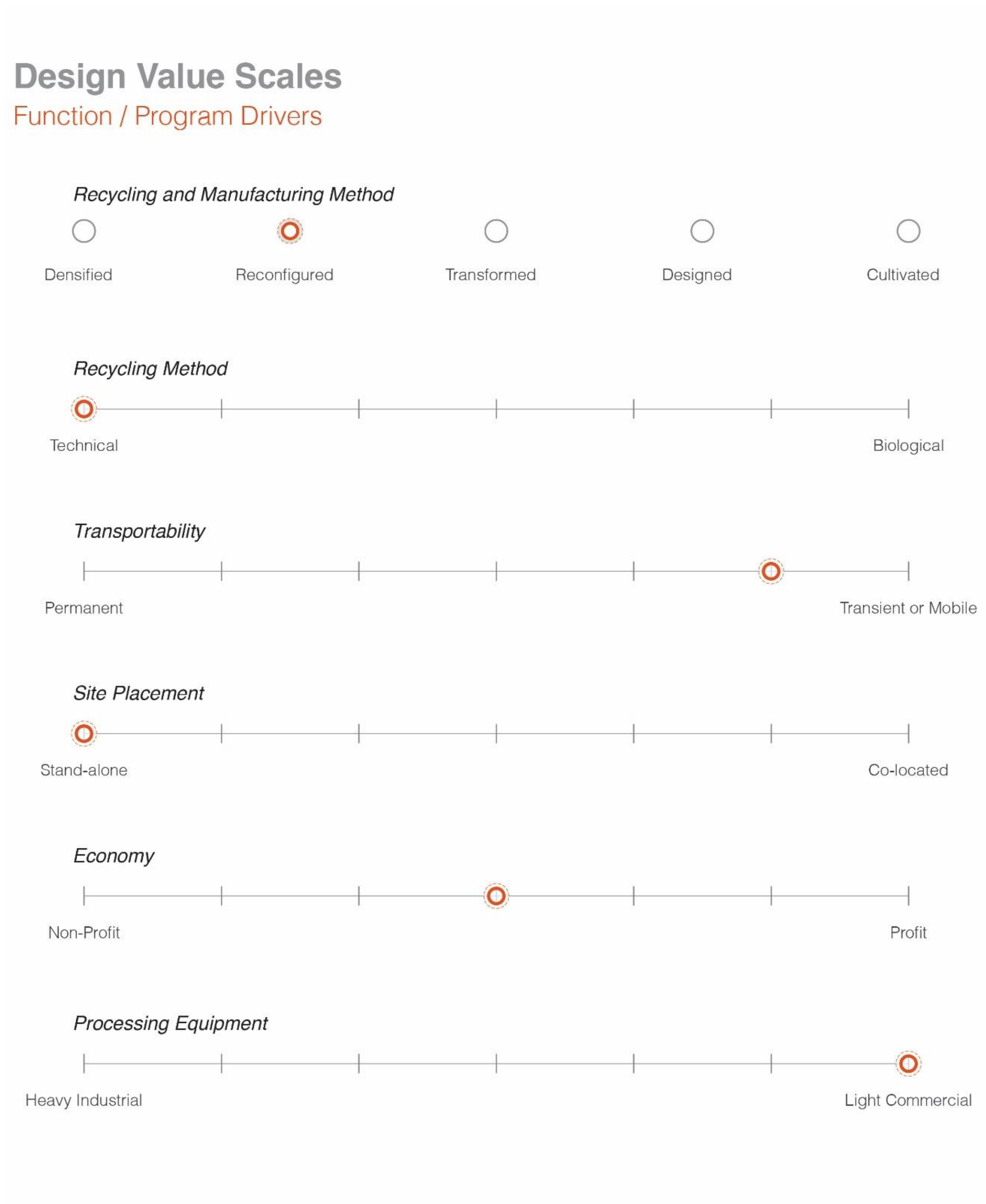



Wood Pallet Waste Recycling
Processes & Building Material Concept Abacus
Deriving the values
Category Relativity
Significance in Design Values
Significance in Design Approach
STRATEGY GROUPS
TACTICAL URBANISM & SMALL-SCALE DESIGN
MOBILE & VERSATILE DESIGN
WASTE DIVERSION & PROCESSING
D.ARCH PROJECT
Design Values
Community engagement
Convenience/accesibility
Incremental solutions
Educational
Pre-fab design
Adaptability
User driven
Replicable
Low environmental impact
Minimal equipment
Economic potential
Cost-efficient
Densified Wood Pallet Waste
Insulation or Particle board
Reconfigured Wood Pallet Waste #1
Cross-laminated wood pallet deckboard panels
Reconfigured Wood Pallet Waste #2
Glued laminated wood pallet deckboard lumber
Transformed Wood Pallet Waste
Wood pallet waste and plastic composite board
Cultivated Wood Pallet Waste
Bio-recycled wood pallet waste as nutrition for mycellum brick cultivation
Sum of Values Extracted
As design drivers for project framework
of/5
2 5 0 5 0 2 5 5 5 5 5 5 4 5 2

1.2 Goals and Objectives

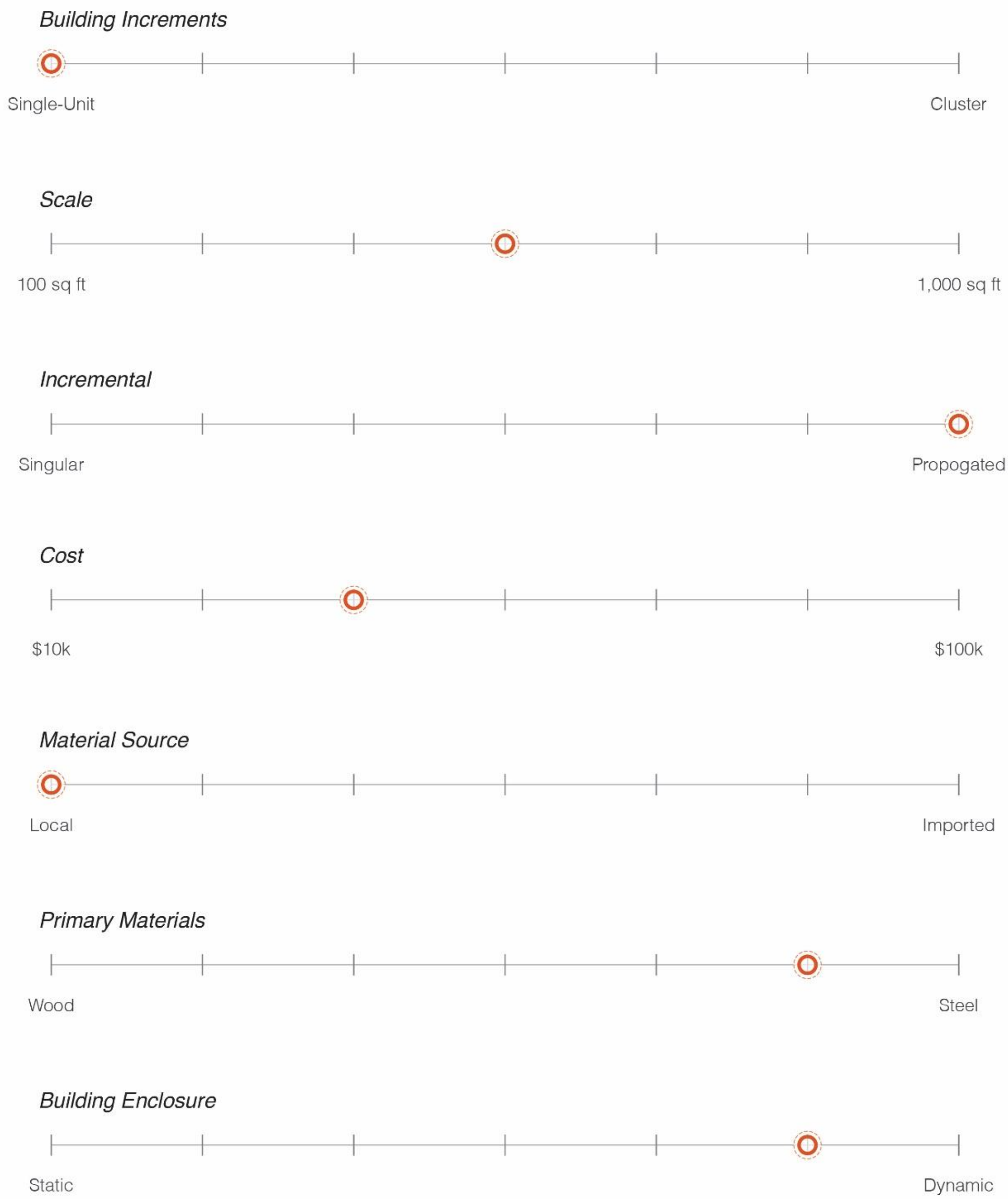
While most of the design values that drive the overall building design will be inherent, there are a few that are more prominent. The decision to design the facility to be mobile or transportable is influenced by the systemized success from Reynolds Recycling the community cultivation from the AMP mobile spacecraft. This attribute would lower cost in terms of structural design and even real property expenses. In order for the facility to be more tactical to insert in various sites and opportunities, it must be small-scale. The primary recycling program within the pilot is also influenced by the waste building material case studies and concept wood pallet waste products. The central recycling processing will focus on glulam or CLT fabrication, as they yield the most product material and require minimal light equipment. To visually see the relevancy of these design values, the following are a series of diagrams depicting the scale of each value that drive the pilot projects function, form and user engagement.

Design Drivers



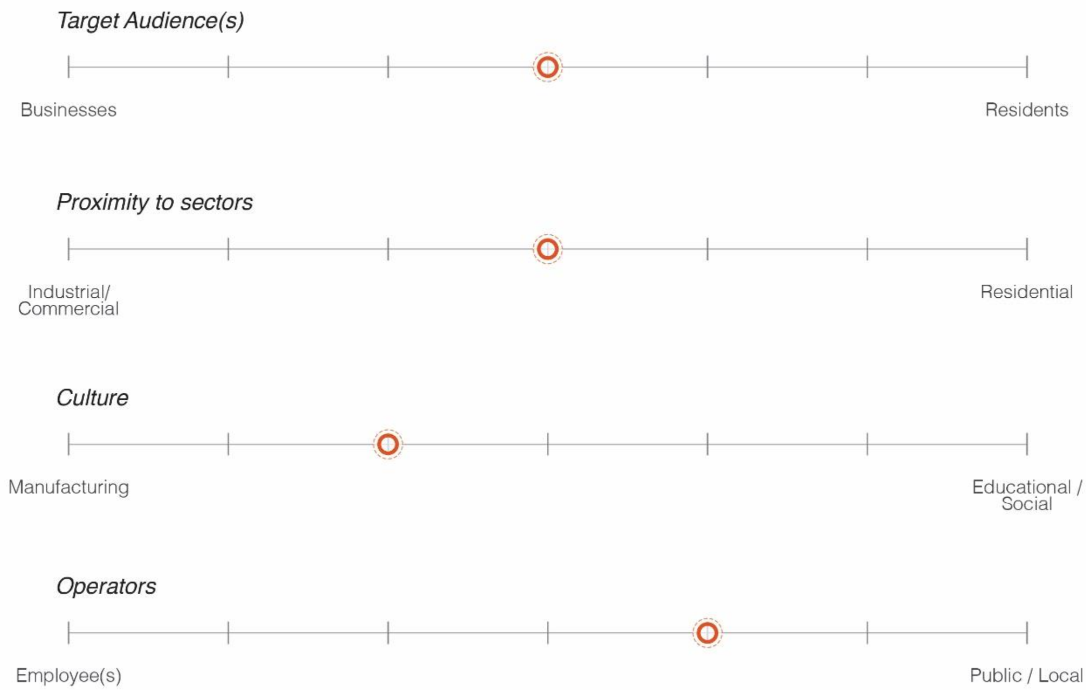
Design Value Scales

Form Drivers



Design Value Scales

User Influences



1.3 Fabrication Shop Layout Design

Reflecting on the previous feasibility studies on glulam lumber fabrication, the quality, and layout of the facility design is no more different than that of a typical wood shop, only this building concept is mobile. There are several essential qualities that a shop should possess that are apparent in a first-class woodworking shop. In his book, *Setting Up Shop: The Practical Guide to Designing and Building Your Dream*, author and professional woodworker Sandor Nagyszalanczy defines those qualities—illustrated in figure 73. These qualities would serve as general principles when composing the wood pallet recycling facility design.

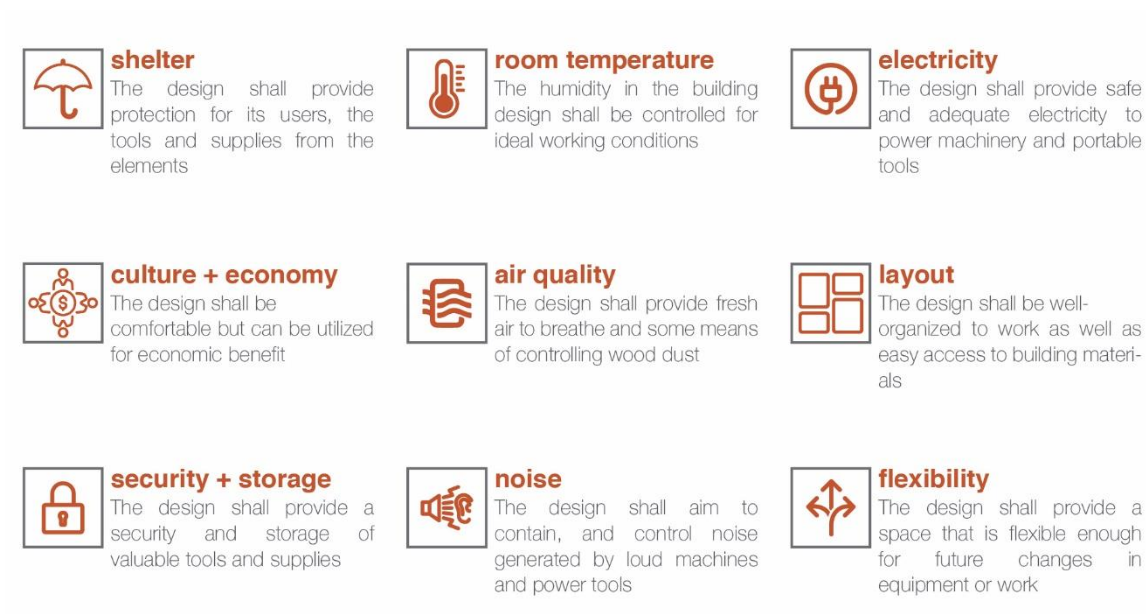


Figure 73. Design aspects for pilot design

Section 2. Physical and Theoretical Site Context

The critical component of the facility design is its placement in an urban context for public use. With a site criterion established, exploring a potential site for a pilot recycling program, it is appropriate to consider the current and future conditions and trends in Hawaii's urban development. And there is no development more prevalent than Hawaii's transit-oriented future, a critical influence on how urban culture, economy, as well as growth in waste streams. The site placement for this pilot recycling facility then gravitates towards the realm of Hawaii's neighborhood transit-oriented development. By allowing this project to be subject to the TOD realm, it would provide insight into areas in proposed plans of opportunities where the design can integrate into. With many discussions on challenging the status quo on Hawaii's wood pallet recycling processes, and now pairing with projected TOD growth, this pilot design of this project would initiate the discussion of how future wood waste could be accommodated.

A critical part of this DArch project and the implementation of the final design proposal is its relevance in future development in Hawai'i. Future growth and urban trends such as the prevalent transit-oriented development in Oahu, is one entity that would affect the very livelihood or our urban communities, and how future growth in waste streams are managed as well. Thus, this project's proposed design subject to such development. How we could start to preemptively intervene within the planning of certain TOD communities to ensure that our waste management continues to innovate to accommodate future wastes while empowering the very communities and people it affects, becomes the integral in the remaining parts of this project.

2.1 Urban Site Mapping

Much of Hawaii's industrial, commercial activity lies within Honolulu, the focal point of Hawaii. Considering that the business sector produces the most wood pallet wastes, the search for a site to deploy the recycling facility design will utilize Honolulu as both an example of deployment and prescribed implementation of this program in an urban setting. By using the criteria created in the previous chapter, the project can discover potential sites within the urban environment that allow an opportunity to deploy this design proposal. Because Transit Oriented Development trends intersect with the same values and components of the design, an analysis of current TOD neighborhood plans will emerge that would support the concept of a new wood pallet waste recycling program.

2.2 Transit Oriented Development

To accommodate a new recycling program to manage our wood pallet wastes in Hawaii a review of our current TOD plans within Hawaii must be conducted. To propose an appropriate site that maximizes the function and program of the facility, it is necessary to seek opportunities in that may have been missed in a proposed TOD plan. We then look into an overview of the stations and neighborhood plans that TOD has curated. Each station services a large community, more importantly altering the urban fabric and culture.

TOD promises to develop many new public facilities and services will contribute to the identity and social equity of the community. However, as the economy continues to grow and more business will open up, the question of how to manage the potential growth of commercial waste such as wood shipping pallets is still unaddressed.

Figure 74. Regional Location of Rail Transit Corridor

Source: Kalihi Neighborhood Transit-Oriented Development Plan 2017

There are many TOD plans spread across the Honolulu Transit corridor plan, each with determined new urban development underway. Because the design proposal calls for a mobile, transient type structure, one that could virtually adapt in many scenarios only requiring few site criteria, this project will select TOD plan that has optimal conditions as well as a need for its placement.

Because Honolulu is center of most commercial and industrial activity, the options for a TOD is narrowed to plans that reside at or near the downtown region of Hawaii. Returning back to the site criteria, the design must be in proximity to the waste resource and the advantageous communities for engagement. Being that the port import and export of Oahu lies within the downtown region of Honolulu near coastal harbors, the TOD plan selection is narrowed down to districts with stations highlighted in figure 75.

Figure 75. Highlighting TOD plans for potential site

Source: https://www.honolulu.gov/tod/dpp-tod-home.html

The City is preparing neighborhood transit-oriented development (TOD) plans that integrate land use and transportation planning around the rail stations in anticipation of the rail project. The plans are intended to address opportunities for new development including rehabilitation and adaptive reuse of existing buildings and assets and to holistically plan for orderly growth and improved accessibility around the stations. The Kalihi Neighborhood TOD Plan addresses land use, local transportation, public facilities and services, economics, infrastructure planning, and implementation around the three Kalihi stations: Middle Street Transit Center, Kalihi, and Kapalama.

Existing Conditions

The three Kalihi rail stations are located in urban Honolulu, as shown in Figure 76. The project location includes industrial/warehouse uses, a transit center, and a portion of Fort Shafter around the Middle Street station; residences and small businesses around the Kalihi station; and Honolulu Community College, big box stores, shops and industrial warehouses around the Kapalama station. Dillingham Boulevard is the major roadway running through the project area and will serve as the spine for the rail line.

Figure 76. Kalihi Rail Stations highlighted on transit corridor map

The Kalihi station area has two distinct characters: makai and mauka of Dillingham Boulevard. Makai of Dillingham, there is a range of uses from engineering offices/machine shops, food industries and warehouses to single-family residential homes. Mauka of Dillingham Boulevard, land uses are generally residential, with some stores and auto-related uses interspersed. Along Dillingham Boulevard, there are a range of small commercial buildings, including fast food, gas stations, offices, banks, and auto uses (e.g., sales and repairs). Notably, nearly all housing units within the three-station planning area are located around the Kalihi station. Most residences are two-story single-family homes with carport parking, though small and mid-size apartment buildings are also found throughout the neighborhood. The Kalihi station area is also home to a park and an elementary and middle school on Kalihi Street. Existing land use of the Kalihi station area can be viewed in figure 77.

Figure 77. Existing Land Use within Kalihi Transit Corridor

Source: Kalihi Neighborhood Transit-Oriented Development Plan. March 2017

Preliminary site selection

The project will look into the Kalihi TOD station radius to narrow down the pilot site. Among the three stations within the Kalihi TOD corridor, this area has an optimal balance of industrial, commercial and residential activity. A key component for sustaining the projects recycling facility operation is its proximity to wood pallet waste generators and community engagement.

Figure 78. Kalihi TOD area within transit station radius

Permits and Variance

When establishing a recycling facility, it is imperative to be aware that it is compliant with land use ordinances, zoning restrictions, as well as acquiring certain permits. Virtually, the proposed design intervention can be adapted in a multitude of settings. It could easily be co-located at an in existing industrial facility, be it an existing recycling operation, which would be an effortless, practical application that may not require further permitting. However, because the project aspires to be more integrated within the residential realm and an accessible public resource, it would then need a special-use permit to operate within a residential zone[57]

Section 3. Site selection

The transient characteristics of the mobile facility design allow itself not to be strictly bound to one fixed site. The benefit of being transportable is that it can be integrated virtually anywhere, as long a few required site components are present and in proximity.

The projects site criteria include:

1. Proximity to wood pallet waste generators
2. Public Access
3. Within an Urban-Mixed Use neighborhood
4. Opportunity site (a vacant or underutilized/undeveloped lot)
5. Large enough to accommodate future additions and program changes
6. Adjacent to an arterial street, for optimal public exposure
7. Parking accommodation

[57] Rivera, Jose. LegalMatch Law Library. 2018

3.1 Searching Opportunity Sites

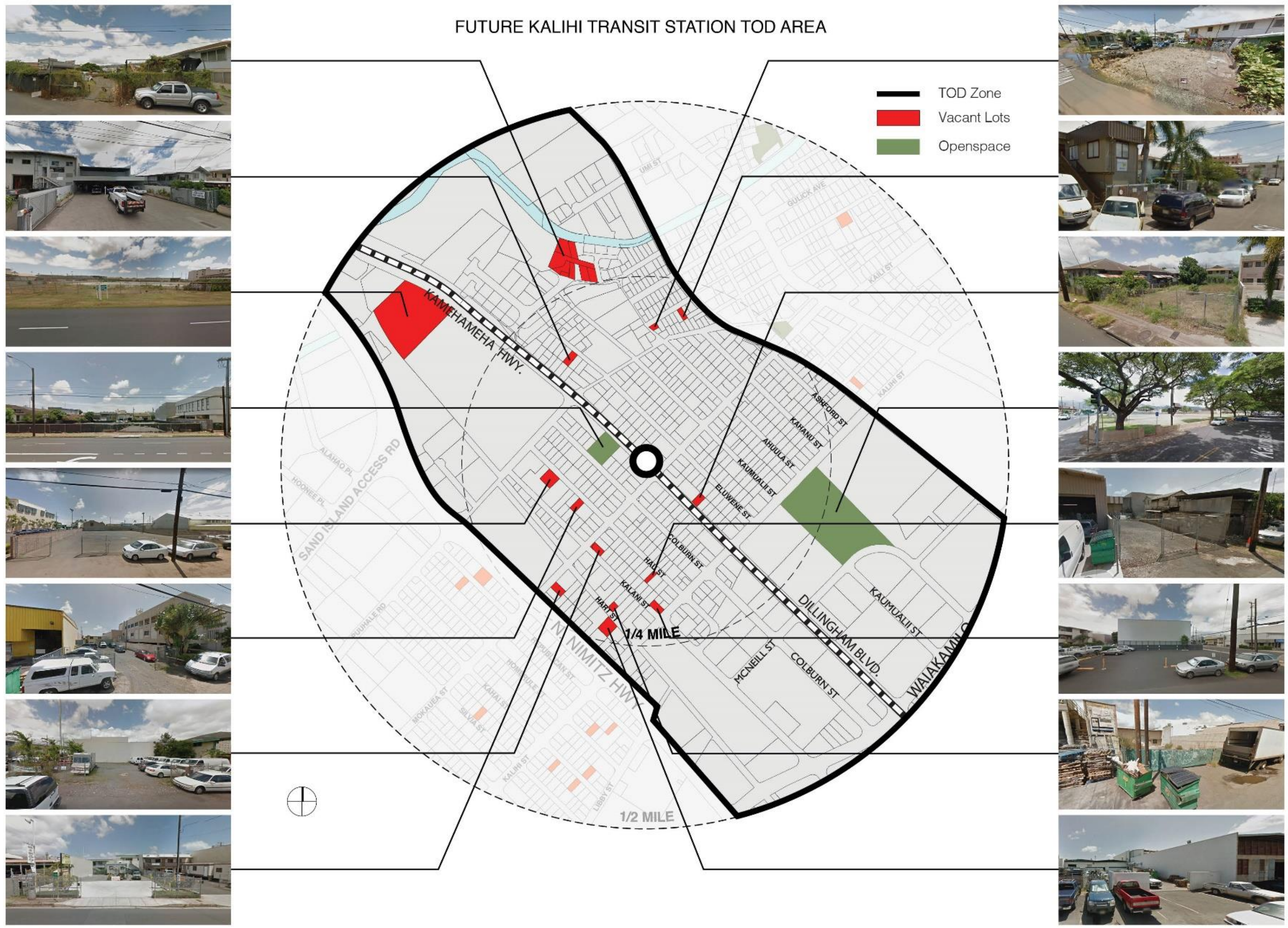
A critical component to siting the facility is to take advantage of underutilized, somewhat vacant spaces in the urban fabric. Narrowing down the site even further, of the three stations in Kalihi, the Kalihi station is selected. This area has a balance and proximity of industrial, commercial and retailers, and residential neighborhoods, making it an appropriate context to place the design proposal. The objective for the siting of this intervention within the Kalihi TOD boundary would not only service the TOD area but may also be open to public beyond. Figure 79 deliberately shows vacant opportunity lots within the ½ radius of the Kalihi Transit Station. To narrow down the site mapping, we can focus more on the lots that have future TOD plans, as shown in figure 80. Because the pilot project concept can be implemented for more current, present opportunities, the demonstration of service this facility on a TOD parcel could perhaps be considered in integration with future TOD planning.

Figure 79. Vacant lots within Kalihi TOD

Reflecting back on tactical urbanism design, this small-scale pilot project can possibly lead to long term change, be an inclusion to future urban development and the community character building. Most of the future land uses within this highlighted TOD boundary site in the Kalihi station would be heavily urban-mixed used and medium dense residential (see Appendix 2 for the future TOD concept plan). Therefore, utilizing a vacant site to test and evoke the potential benefits of this pilot project is appropriate for this particular context. With a plethora of existing businesses within the area, especially being near industrial zones, there is an existing waste resource waiting to be capitalized. 16 parcels are highlighted each one different in scale, site, and zone characteristics.

Figure 80. Narrowing vacant lots within proposed TOD region

FUTURE KALIHI TRANSIT STATION TOD AREA



15" FOLDED PAGE

Final Pilot Site Selection

The highlighted vacant parcels shown currently are either unutilized, leased for business-related operation, or merely additional parking. By using our site criteria to provide a quality assessment, we can start to eliminate sites from consideration. Located on Dillingham Blvd, in proximity to the future Kalihi Transit station is a lot made up of six parcels, currently leased by the State as a truck yard for Honolulu's Freight Service company. Among of the previous top three sites, this location is selected because of its optimal exposure to one of Kalihi arterial street (Dillingham Blvd) giving the pilot recycling facility decent exposure to the public, as well as access. The lot is considerably large, stretching across the tax plat creating access from two streets: Dillingham Blvd and Colburn St. Consideration that the design can be incremental, the site can easily accommodate future additions if needed. This particular lot, however, is also planned to be a new open space/park as proposed in the Kalihi TOD concept plan (see Appendix 2).

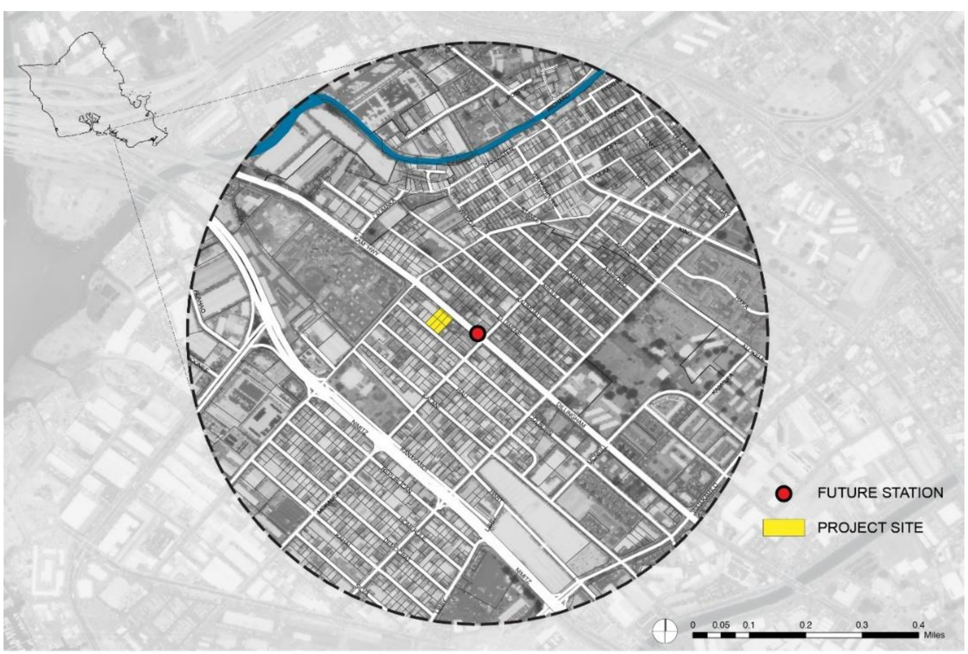


Figure 81. Opportunity lot selection at TOD scale view

Owner and Parcel Information			
Parcel Number	120091060000	**Data current as of**	March 18, 2019
Owner Name	KASHIWA,GENRO TRUSTEE Fee Owner HAWAIIAN HOST INC Lessee	**Project Name**	
Location Address	1965 DILLINGHAM BLVD	**Plat Map**	
Property Class	INDUSTRIAL	**Parcel Map**	
Land Area (approximate sq ft)	4,003	**Legal Information**	
Land Area (acres)	0.0919	POR. LOT 17 & REM PAR 401C BLK 9 "KAPIOLANI TRACT" POR. RP 8194 LCAW 6450 APANA 1	

Figure 82. Parcel scale view of pilot site with ownership details

Source: City and County of Honolulu, Department of Budget and Fiscal Services Real Property Assessment division.

Highlighted in a tax map in Appendix 4, as well as a zoomed in view in the plan above is a detailed, dimensional view of our pilot site in context with adjoining properties.

Conclusion

Reiterating with the objectives of this research project, the goal for the design has not been to be an all-perfect solution to eliminate all wood pallet wastes in Hawai'i but to encourage the dialog of how small-scale solutions can start to tackle these niche waste streams. The goal is to pilot a small program to garner enough attention and success that could lead to influencing government to see the value in perhaps establishing a more coordinated program and facility dedicated to diverting more wood wastes in conjunction with building community culture and economy in the process. The benefit to the state is that this is a preemptive alternative solution to diverting future wood waste from reaching our Hawai'i landfills. If implemented, this pilot project if could have the potential on influencing local government to consider the integration of such program with future TOD planning in the area. Thus, creating long term change by small-scale interventions.

PART 5 | Pilot Design

Part 5 Pilot Design

With an opportune site for optimal placement of the pilot recycling program, coupled with a diverse design framework, we now transition towards the final stages of this project: building design. The convergence of all previous research, precedent studies, and the design values derived will start to manifest themselves within the design decision making process. Some influential design aspects having greater importance than the other, that constrict and construct a design language. This last chapter begins this process with the schematic design concept of the overall building structure. The design is developed further with the application of previous fabrication and manufacturing facility design research; creating spaces and procedures that support the material processing efforts. Lastly, a brief discussion on further possibilities and implications of this concept pilot project.

Section 1. Schematic Building Design

1.1 Building enclosure

Among the many design values and strategies explored, Mobility, Low-Cost, Recycle, holds the most significant influence on the projects design approach. This allows for both practicality and consistency with the theme of the project of product-life extension, a segue into the rationale for utilizing a repurposed shipping container for our facility's enclosure design. Initially, the building design concept focused primarily on creating the structure with remanufacturing wood pallet waste building material onto a retrofitted trailer bed. However, considering the labor, cost, time, overall structural integrity and practicality, it was deemed unfeasible. Repurposing a retired shipping container, on the other hand, became the next suitable approach.

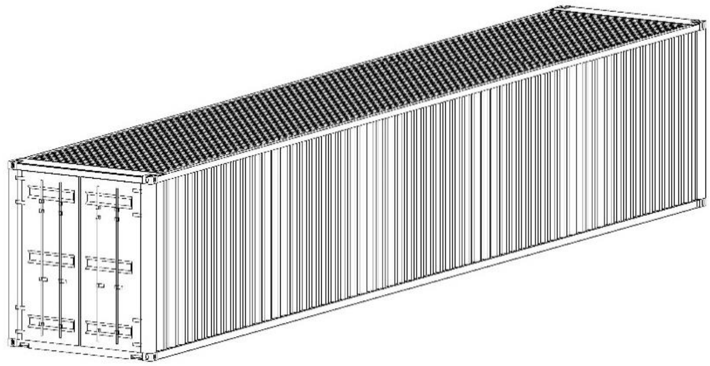


Figure 83. Axonometric view of a shipping container unit

Source: Author

Shipping Container Reuse

The major factor in deciding to use a shipping container unit as a building design module is because it's readily available, structurally stable, weather-proof, transportable, small-scale and inexpensive. Thus, rendering it viable for the scale and purpose of the pilot project. And considering that the facility will be equipped with vital equipment, shelter from the elements as well as theft prevention also became additional factors. Also, because they are transportable, they are not subjected to costly real property fees. This refers back to the projects low-cost and small-scale approach.

While there many shapes and sizes of shipping containers, only few are typically ideal for human habitation. This project will utilize one of the largest container sizes available on the market: the 40 ft shipping container. This 40ft shipping container, the storage container is considered a High Cube container. High Cube shipping containers, storage containers are 9ft 6in tall on the exterior. They are 1ft taller than the standard height container. The container is comprised of 14-gauge corrugated steel panels throughout. It is equipped with 1-1/8" thick marine plywood flooring on the interior.

Figure 84. Exploded axonometric view of a shipping container unit

Source: Residential Shipping Container Primer (RSCP™)

The illustration above displays the components that make up a typical shipping container unit. (See appendix 5 for dimensional specifications).

Sourcing a local container

There are many companies that sell and lease shipping containers both locally in Hawai'i and on the mainland. The project will preferably seek a local company and perhaps a used shipping container, to maintain cohesive with the project's goals using local and reusable materials. Two major companies on the island that provide shipping containers for sale or for rent: *Containers Hawaii* and *Makai Container & Equipment Solutions.* Both companies offer many containers sizes in new or used conditions. They also provide container customization services and pre-fab containers offices for sale. At the date of this research project, their prices for a 40' shipping container are listed below.[58] [59]

Figure 85. Local shipping container vendors

Source: Containers Hawaii, Makai Container & Equipment Solutions.

The method to transport the pilot recycling facility can be done in several ways. The container module can be attached to a chassis trailer which then can be hooked onto a truck to be transported. For this project, we will focus on a stationed/grounded setup.

[58] Containers Hawaii. *Shipping Cargo Containers for Sale or Rent.* https://containershawaii.com/
[59] Makai Container. *Hawaii Shipping Containers For Sale.* https://www.makaicontainer.com/

Retrofit Design

With a plethora of repurposed or retrofitted shipping containers examples in the world to leverage on, this schematic design phase explores possible ways to alter the building form to best suit the function of the pilot project. Among of the wood shop design qualities, we will integrate for the project, we can look at the aspect of *flexibility* to be a driver for how we can retrofit a shipping container unit to accommodate our fabrication process design.

Expandable Design

To allow for a larger working area within the facility design, the concept is to open up one side of the shipping container. This would include cutting through the corrugated metal façade and providing structural brace to support the container's roof. To expand the floor area, the concept is to install an operable garage-door wall type assembly within the newly removed façade. Because of the length of the shipping container, a set of three-expandable wall assembly units are installed, to allow easier fold up and break down. While keeping in mind to keep building material costs low and light-weight, components of the custom wall assembly utilize lightweight structural steel and corrugated sheet metal sheathing on the exterior. Early schematic renderings of this design can be seen in figure 87 and 88.

Program layout

To work with the spatial conditions of a shipping container, the fabrication layout of our project will optimize the shape and length of the unit to organize the process for the production of glulam building materials. Figure 86 diagrams an early concept of the volume of a shipping container being divided into four essential components of an ideal fabrication lab.

The process starts with sorting; where lumber extracted from wood pallets are graded and organized. In the next step, the maker processes and mills the reclaimed lumber to workable dimensions. A storage component is integrated within the layout; however, a separate container or storage unit would be a more efficient, alternative. The “Make” space are areas where the worker can produce or assemble pieces of work.

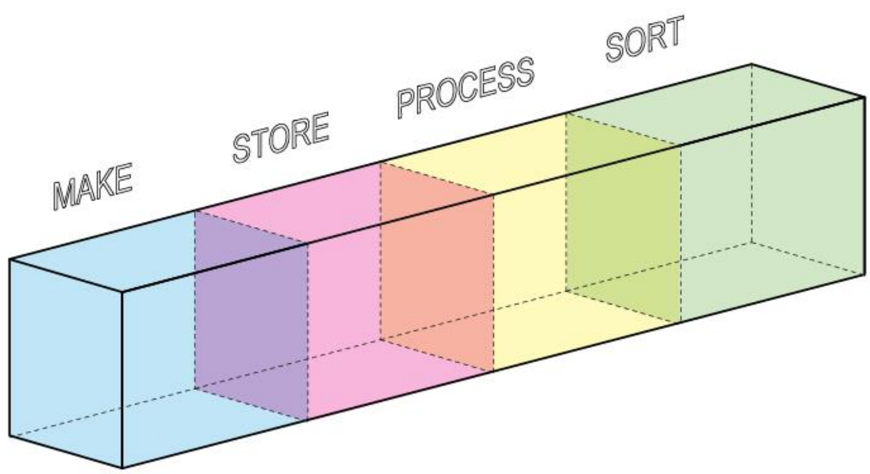


Figure 86. Diagram of recycling program work flow

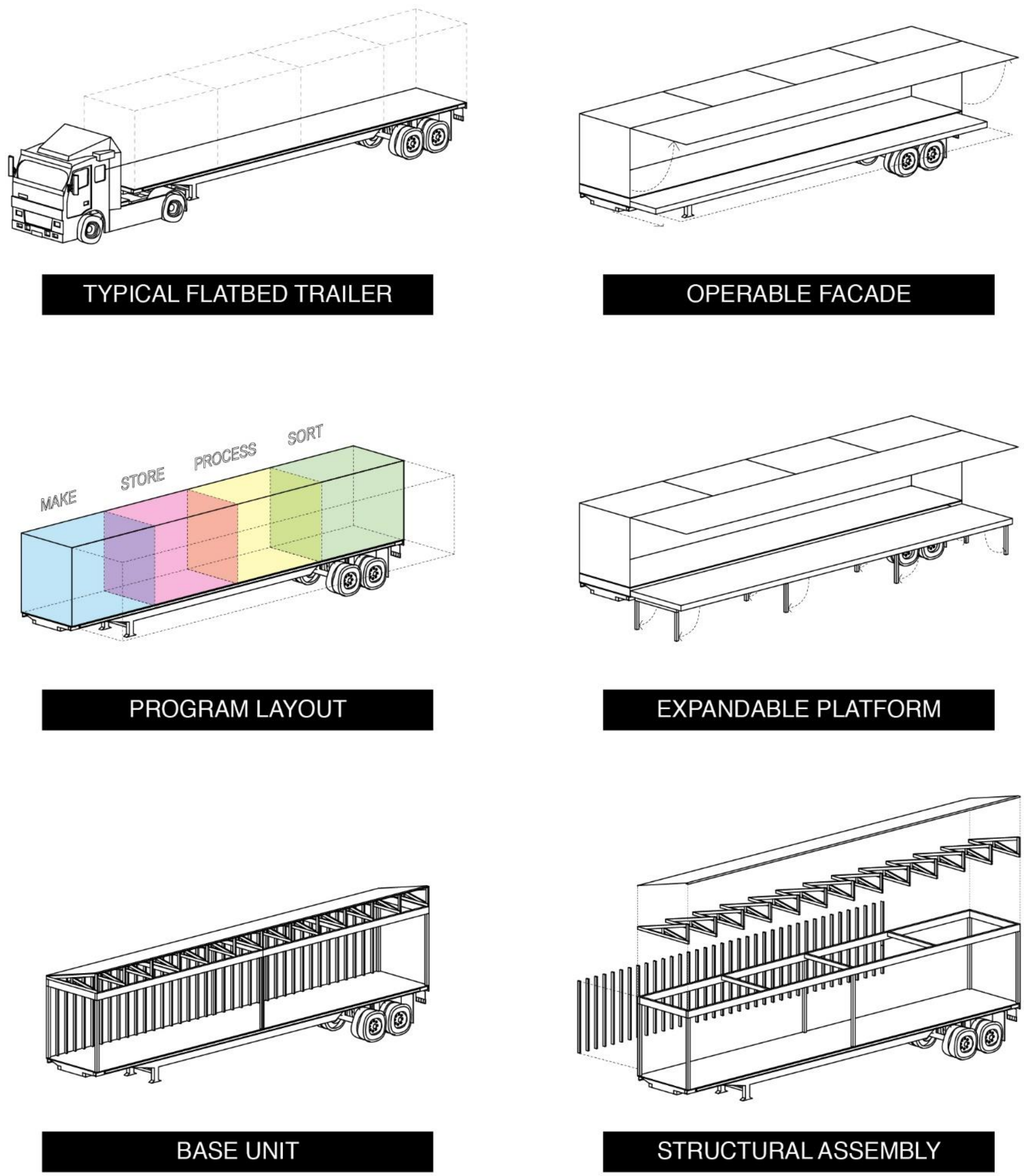
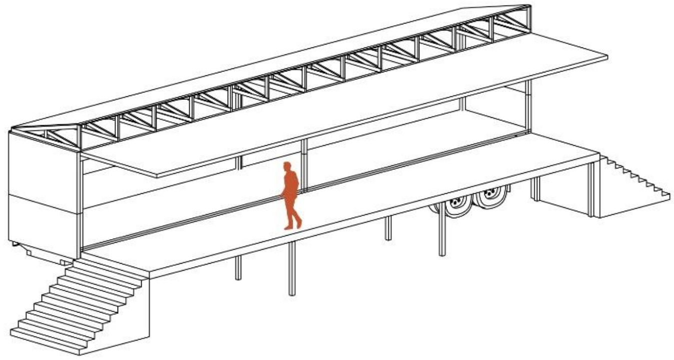
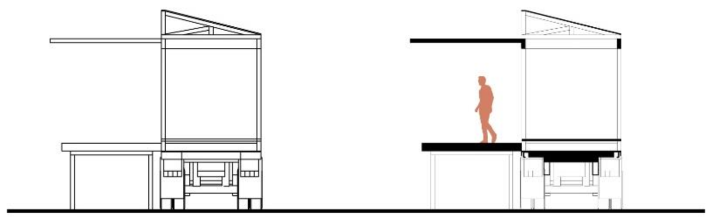


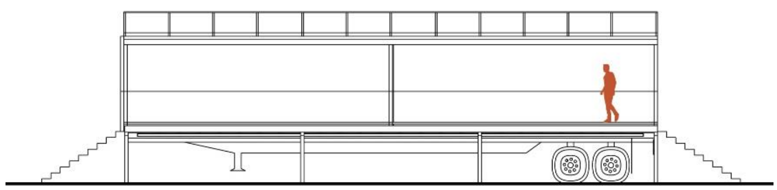
Figure 87. Early conceptual line drawing of the building's tectonics



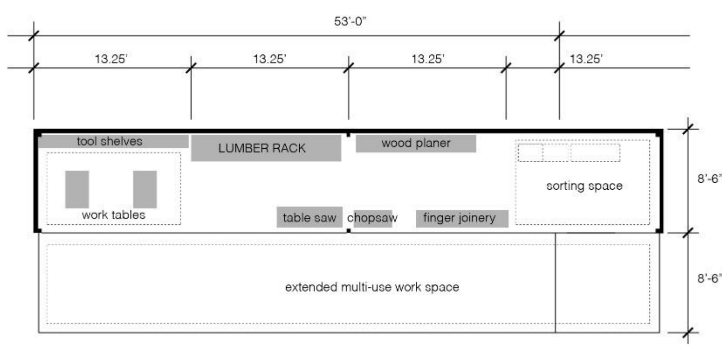
Early concept perspective



East Elevation and Section Cut



North Elevation



Processing workshop plan

Figure 88. Early building form concepts diagrams

Section 2. Design Development

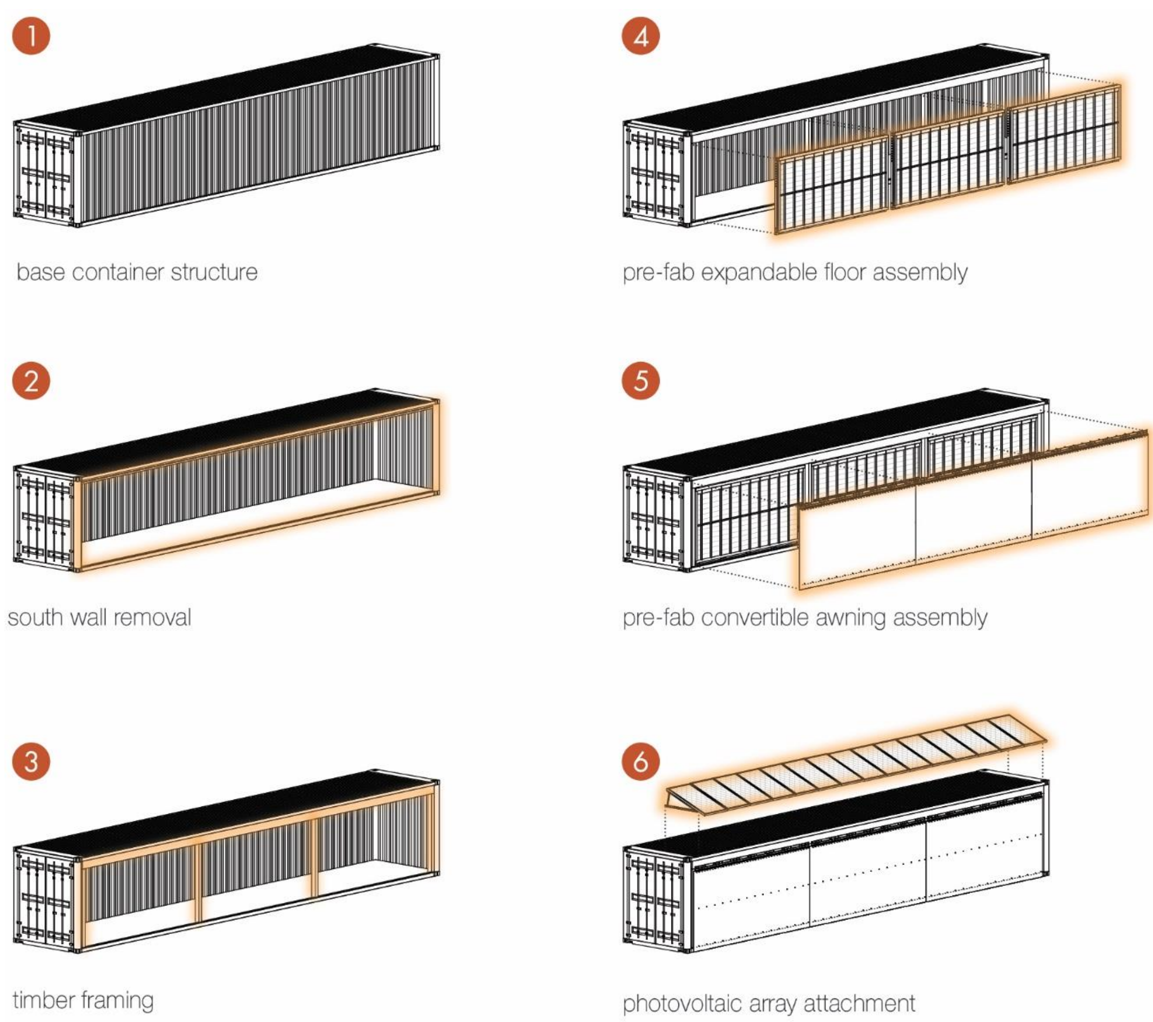


Figure 89. Graphic illustration of developed container conversion design.

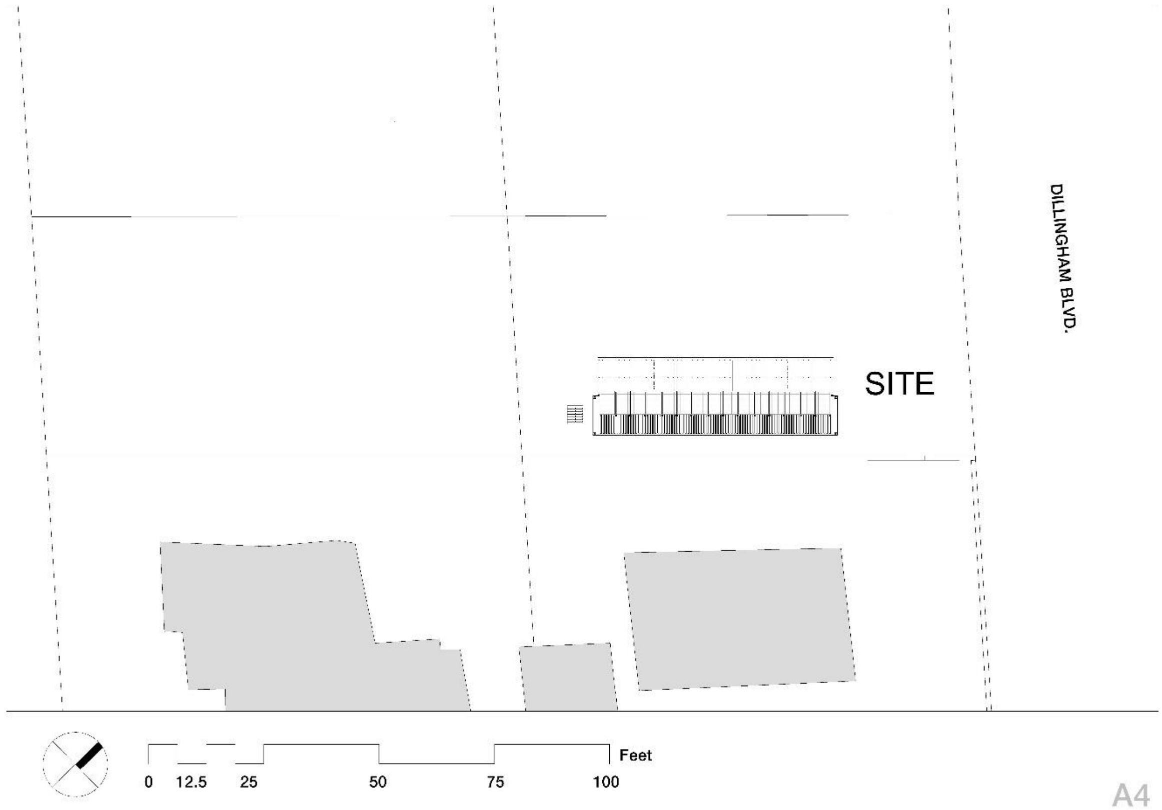


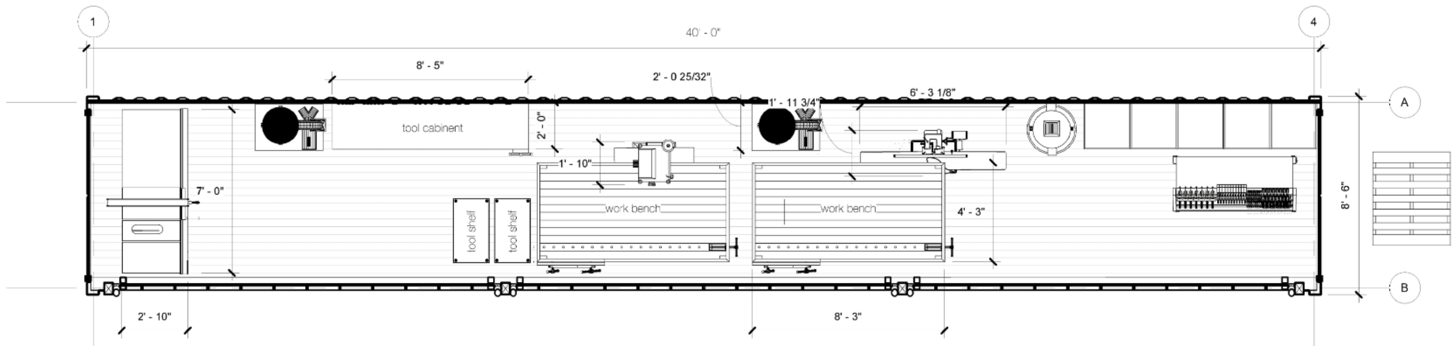
Figure 90. Site plan of Pilot design

Site Placement

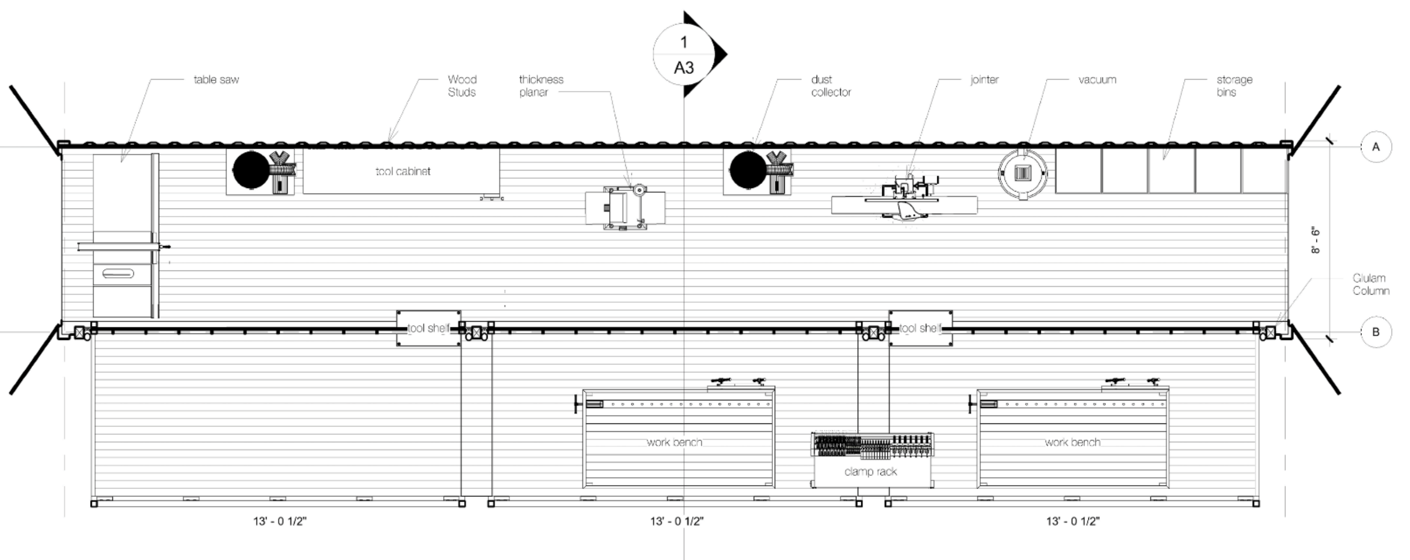
Of the six parcels that make up the lot of our pilot project site, one is sufficient enough for the placement of our mobile recycling facility. People can easily access the main arterial road (Dillingham Blvd) to arrive into the site or utilize the local roadway (Colburn St) behind because the site stretches to both streets. Because the design is incremental and is a container unit, there is potential that multiple placements of this design can populate the area.This could give the opportunity for another type of recycling or waste building material manufacturing operation.

Pilot Design Floor Plan

Opened and Closed Scenario



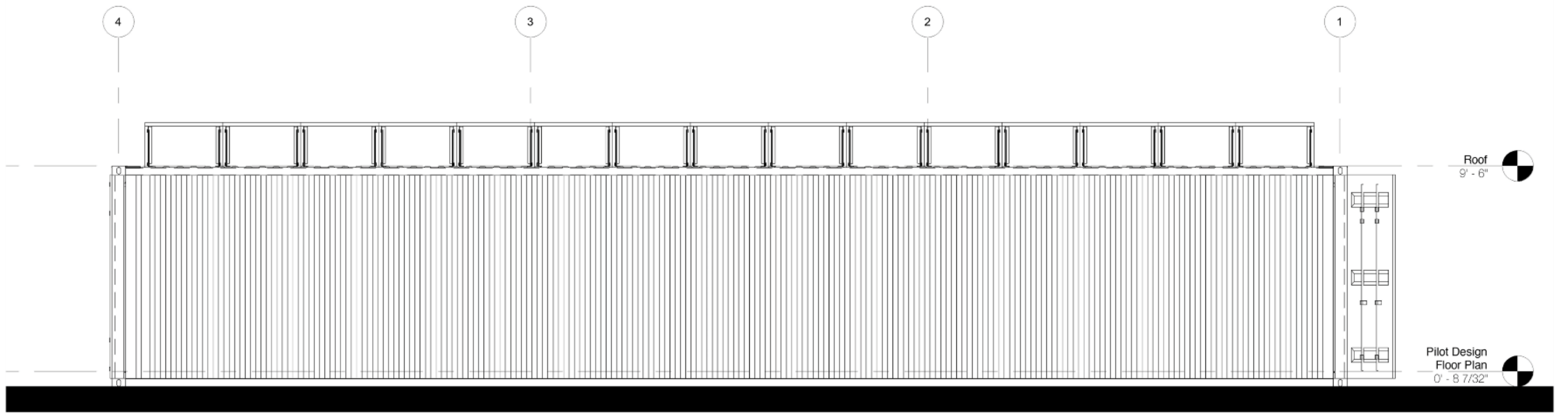
1 Pilot Design Floor Plan - Closed
3/16" = 1'-0"



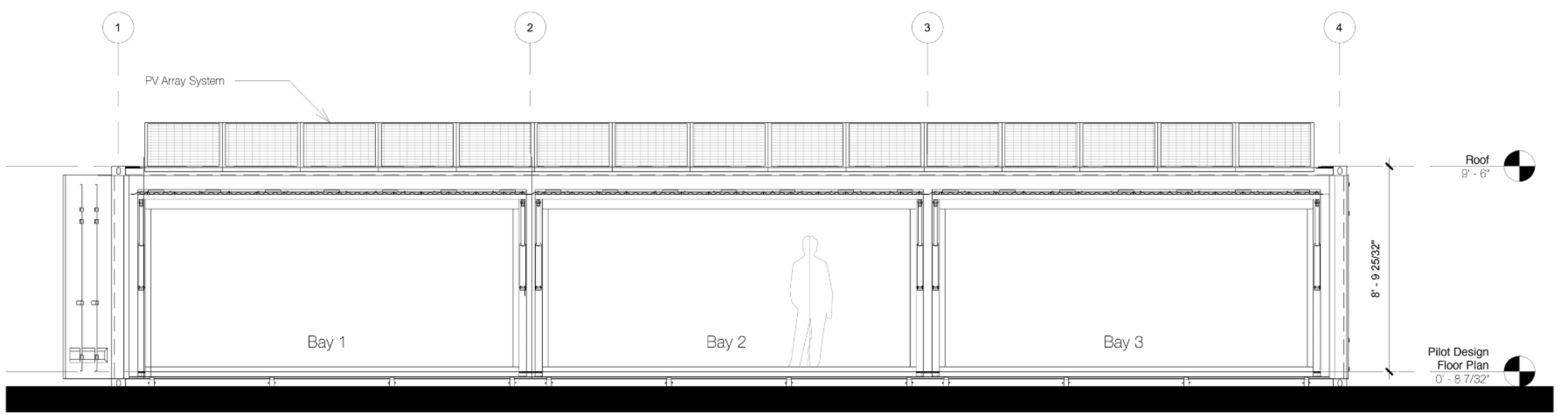
2 Pilot Design Floor Plan - Expanded
3/16" = 1'-0"

A1

Pilot Design Elevations



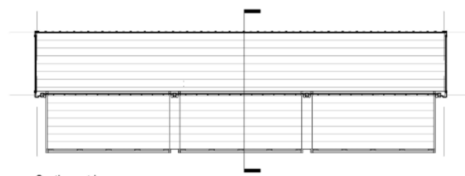
1 North Elevation
3/16" = 1'-0"



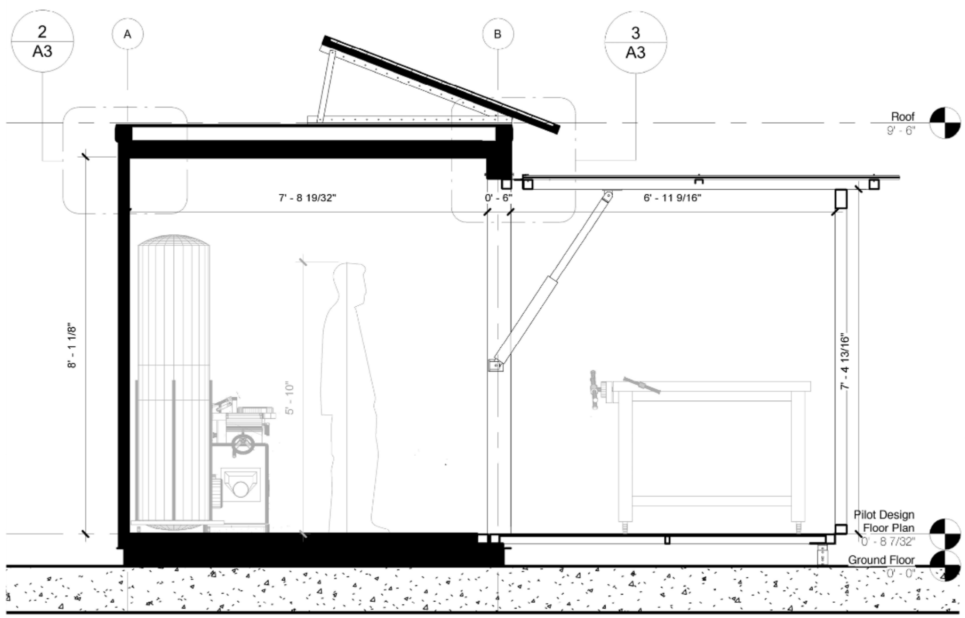
2 South Elevation
3/16" = 1'-0"

A2

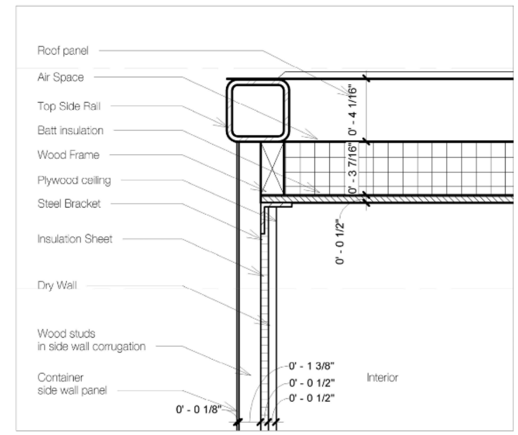
Pilot Design Section Cut



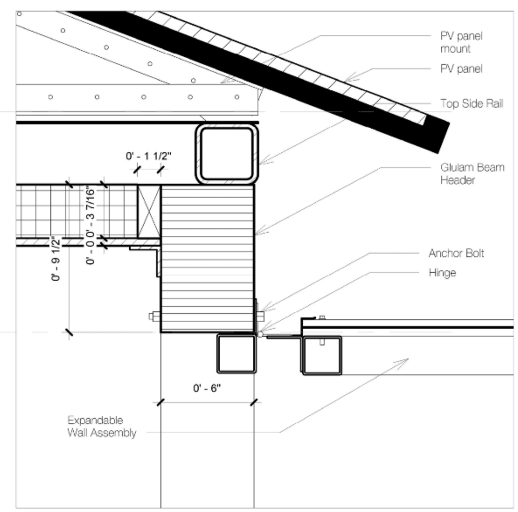
Section cut key



1 Transverse Section Cut
3/8" = 1'-0"



2 Section Detail 1
1 1/2" = 1'-0"



3 Section Detail 2
1 1/2" = 1'-0"

A3

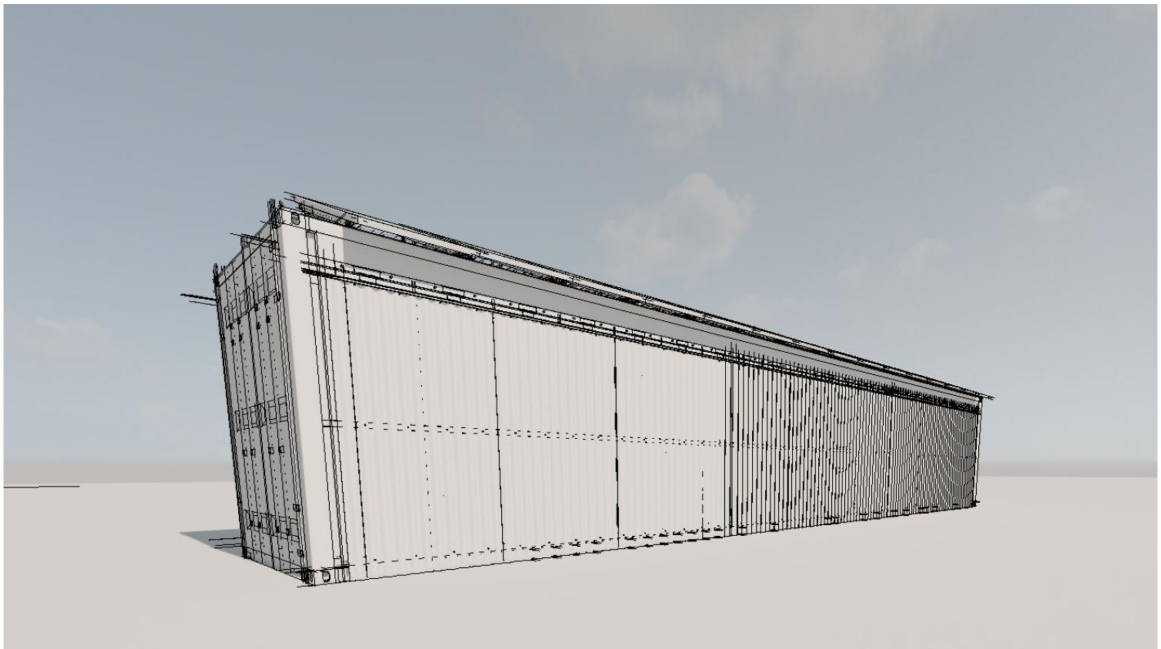


Figure 92. Closed facade

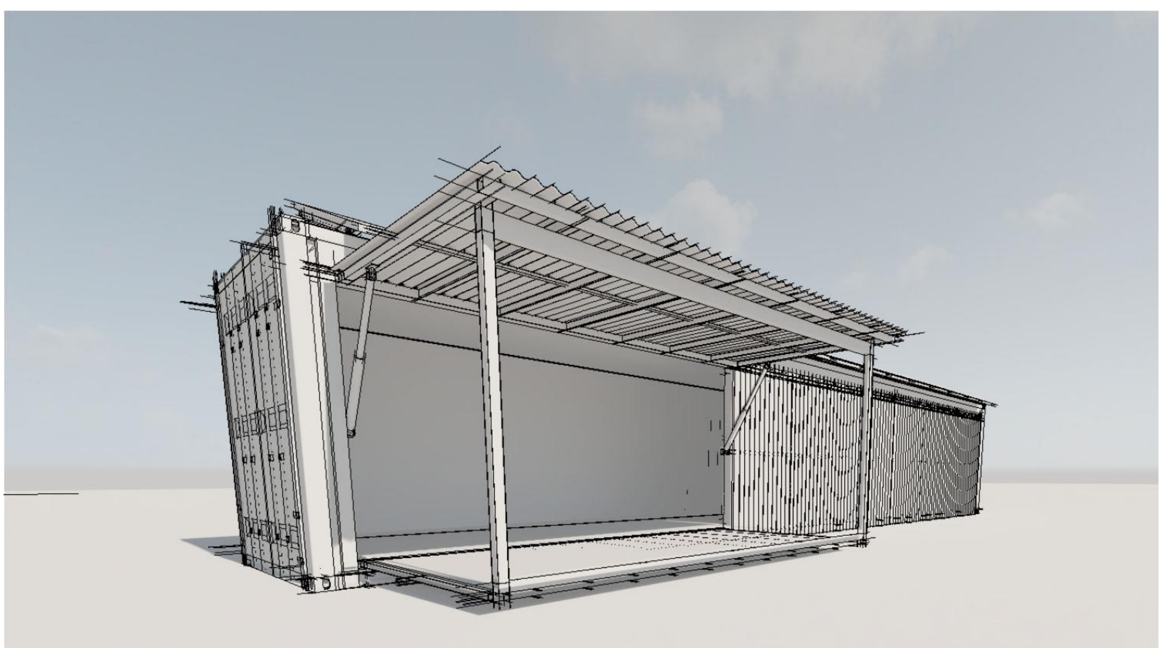


Figure 92. Expanded work space

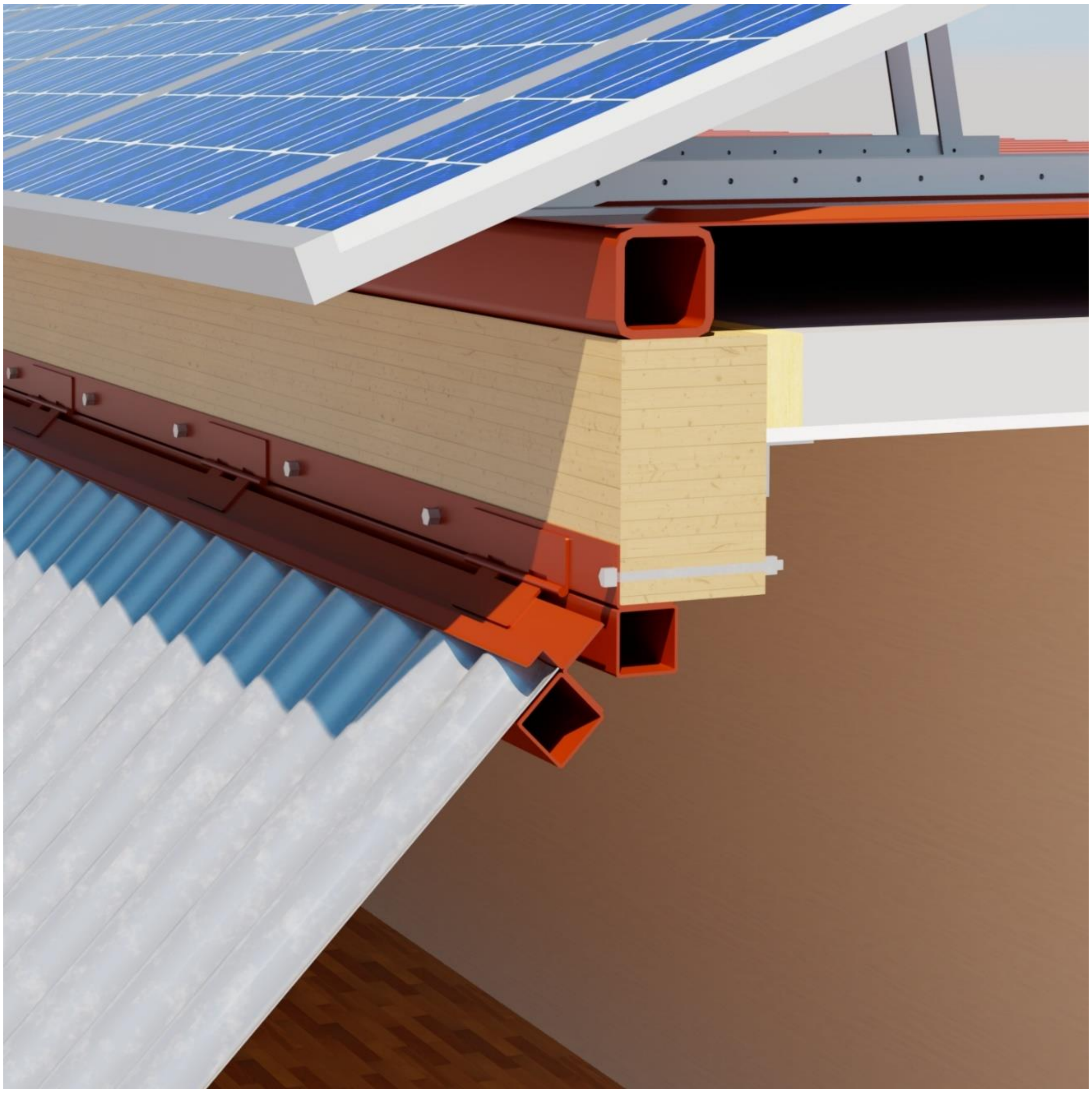


Figure 93. Section perspective detail rendering of convertible facade design and reclaimed wood pallet waste – glulam beam

Figure 95. Exterior rendering of pilot design with walls closed

Figure 94. Exterior rendering of pilot design with walls closed

Figure 97. Interior Rendering

Figure 96. Section perspective rendering

Implications of the research

The implications of this research have the potential to influence policies regarding how Hawaii manages niche waste streams such as wood pallet wastes. Hawaii businesses can utilize this recycling program as alternative disposal for their shipping pallets. This, in turn, would support local communities and economy. The research did not discuss much detail on the socio-economy benefits that this intervention may have on our local communities, but if implemented and managed by local individuals, new jobs and cultures in wood recycling could emerge.

This project was heavily focused on the context and constraints of Hawaii. A design like this, however, can be easily be adapted in other settings where wood pallet waste is being undermanaged. The facility system and design are directly replicable, but the products fabricated are customizable. There are many individuals interested in building and construction but may lack the resource or tools. By providing this as a public resource, it can bring value to a community or a future maker.

Low-cost, small-scale, and mobile design were critical drivers for this wood pallet recycling facility model. The scale of the product was influenced by the scale of the fabrication system. But the value regenerated from something that was once a candidate for incineration or mulch proves that a significant impact can emerge from small, simple solutions. To see a more significant result, however, a collaboration with state agencies to standardize this recycling program would be necessary. It is only through small projects such as this, that could begin that process.

Final Remarks

The project focused on one material waste stream to produce waste building construction materials, while there were several more methods that theoretically could also be done. There is still potential to create multiple pilot recycling units that manufacture different kinds of building materials from wood pallet wastes. Glue-laminated timber was only one of the many products that could emerge from remanufacturing wood pallet wastes. Structural testing of these products is also a critical component for its viability in a residential application. These studies were not possible with the time constraints of this project. Therefore, a continuation of this line of research to uncover that area of inquiry would add to the value and justification for this pilot design.

Aside from wood pallet wastes, there are dozens of niche waste streams that could be activated for reuse or remanufacturing. Low-cost and small-scale design approach these challenges can help bring these waste streams to light. By utilizing modern day technology, innovate thinking and design, we can eliminate or at least divert more wastes from generating not just in Hawaii, but for the communities and countries around the world. Collectively, we can attenuate the ramifications of pollution and global warming.

Works Cited

Aldraz-Carroll, Enrique, and Gael J.R.F Raballand. 2005. "How do differing standards increase trade costs? The case of pallets." Policy Research Working Paper.

APA - The Engineered Wood Association. 2017. "Glulam Product Guide." *www.apawood.org.* February. Accessed November 3, 2018. https://www.apawood.org/glulam.

APA - The Engineered Wood Association. 2016. "Cross-Laminated Timber." *www.apawood.org.* July. Accessed November 3, 2018. https://www.apawood.org/cross-laminated-timber.

Block Research Group. n.d. *ETH Zurich Pavilion, New York City, USA, 2015.* Accessed November 2, 2018. http://block.arch.ethz.ch/brg/project/eth-ideas-city-pavilion-new-york-ny-usa.

Boulze, Dimitri, Quentin Jeandel, and Heather Stiletto. 2018. *Wood Pallet: Is it Safe For Reuse For My Next DIY Project?* June 29. Accessed October 15, 2018. https://www.1001pallets.com/pallet-safety/.

Buehlmann, Urs, Matthew Bumgardner, and Tom Fluharty. 2009. "Ban on landfilling of wooden pallets in North Carolina: an assessment of recycling and industry capacity." *Journal of Cleaner Production* 271. doi:10.1016/j.jclepro.2008.06.002.

Bush, Robert J, Philip A Araman, and E. Bradley Hager. 2011. "Hardwoods in U.S. Wood Pallet Production." *Proceedings of the 3rd International Scientific Conference on Hardwood Processing* 197-202.

Campos, Fabio, and Tatiana Soster. 2018. "Whats a makerspace for?" *Fablearn Europe 2018.* Trondheim, Norway. 106-107.

Carrano, Andres L, Brian K Thorn, and Henry Woltag. 2014. "Characterizing the Carbon Footprint of Wood Pallet Logistics." *Forest Products Journal* 64 (7-8): 232-241.

City & County of Honolulu, Department of Environmental Services. n.d. *Recycling and Landfill Diversion.* Accessed November 2, 2018. http://www.opala.org/solid_waste/archive/facts2.html#msw.

City and County of Honolulu. 2016. August 10. Accessed April 1, 2019. https://www.honolulu.gov/tod/dpp-tod-home.html.

City and County of Honolulu. 2006. "2006 Waste Characterization Study." Government Report, Department of Environmental Services, Honolulu.

http://www.opala.org/pdfs/solid_waste/2006%20Final%20Waste%20Characterization%20Report.pdf.

City and County of Honolulu. 2017. "Kalihi Neighhoborhood Transit-Oriented Development Plan ."

City and County of Honolulu. 2017. "Oahu Waste Composition Study."

Containers Hawaii. n.d. *Shipping Cargo Containers for Sale or Rent.* Accessed March 4, 2019. https://containershawaii.com/.

Cooney, Scott. 2012. "The Economics of Recycling in Hawaii." *Hawaiʻi Business Magazine,* August 6. Accessed October 15, 2018 . https://www.hawaiibusiness.com/the-economics-of-recycling-in-hawaii/.

Corr, Daryl T. 2000. "The Status of Wood Pallet Disposal and Recovery at United States Landfills." Master's Thesis, Blacksburg, Virginia.

Department of Environmental Services. n.d. *www.opala.org.* Accessed October 15, 2018. http://www.opala.org/solid_waste/archive/How_our_City_manages_our_waste.html.

DIVISARE. 2012. June 5. Accessed November 2, 2018. https://avatar-architettura.divisare.pro/projects/201524-pallett-pavillion.

EPEA. n.d. *https://www.epea.com.* Accessed October 16, 2018. https://www.epea.com/cradle-to-cradle/.

Gardner, Gary. 2012. *Urbanizing the Developing World | Vital Signs Online.* July 24. Accessed November 30, 2018. http://vitalsigns.worldwatch.org/vs-trend/municipal-solid-waste-growing.

Girardet, Herbert. 2001. *Creating Sustainable Cities.* Green Books for the Schumacher Society.

Hawaiʻi Tourism Authority. 2017. "2017 Annual Visitor Research." Annual Visitors Report, Hawaii. Accessed October 31, 2018. https://www.hawaiitourismauthority.org/media/2638/2017-annual-report-posting.pdf.

Hebel, Dirk E, Marta H Wisniewska, and Felix Heisel. 2014. *Building from Waste: Recovered Materials in Architecture and Construction.* Basel: Birkhäuser.

Holler Architecture. n.d. *Nosara Recycling & Education Center.* Accessed November 8, 2018. https://architizer.com/projects/nosara-recycling-education-center/.

Hoornweg, Daniel, and Perinaz Bhada-Tata. 2012. "What a Waste: A Global Review of Solid Waste Management." *World Bank - Urban Development Series Knowledge Papers*, March 12.

Kaneyuki, Darryl. 2018. "The Future of Recycling in Hawai'i." *Hawaii Business Magazine*, September 10. https://www.hawaiibusiness.com/the-future-of-recycling-in-hawaii/.

Longva Arkitekter. 2016. *Smestad Recycling Centre / Longva Arkitekter.* April 21. Accessed November 8, 2018. https://www.archdaily.com/785900/smestad-recycling-centre-longva-arkitekter.

Lydon, Mike, and Anthony Garcia. 2015. *Tactical Urbanism: Short-term Action for Long-term Change.*

Makai Container. n.d. *Hawaii Shipping Containers For Sale.* Accessed March 4, 2019. https://www.makaicontainer.com/.

Mazeika Bilbao, A., A.L. Carrano, M. Hewitt, and B.K. Thorn. 2011. "On the environmental impacts of pallet management operations." *Management Research Review* 1222-1236. doi:https://doi.org/10.1108/01409171111178765.

McDonough, William, and Michael Braungart. 2002. *Cradle to Cradle: Remaking the Way We Make Things.* First Edition. Madrid: McGraw - Hill.

Meinhold, Bridgette. 2012. *Inhabitat Green Design Innovation Architecture Green Building.* October 24. Accessed November 2, 2018. https://inhabitat.com/foret-ii-is-a-meditation-pavilion-made-from-810-reclaimed-shipping-pallets/.

Noll & Tam Architects. n.d. *El Cerrito Recycling Center. A Living Model of Net-Zero Waste, Restoration and Regeneration.* Accessed November 8, 2018. http://www.nollandtam.com/portfolio/civic_transit/el_cerrito_recycling_and_environmental_resource_center.

Rambaud, Coline, Jaime Galan, and Cintia Cernadas. 2015. June 3. Accessed November 3, 2018. https://community.oscedays.org/t/challenge-rediseno-de-un-palet-de-madera/558.

Re-use Hawai'i. n.d. *Re-use Hawai'i.* Accessed January 11, 2019. http://www.reusehawaii.org/home.php.

Rivera, Jose. 2018. *LegalMatch Law Library.* June 5. Accessed March 26, 2018. https://www.legalmatch.com/law-library/article/what-is-a-special-use-permit.html.

Shimogawa, Duane. 2008. "Trash problems not only impacting Oahu." *Hawaiʻi News Now*, September 25. Accessed November 1, 2018. http://www.hawaiinewsnow.com/story/9077420/trash-problems-not-only-impacting-oahu/.

Stahel, Walter R. 2016. "Circular Economy: A New Relationship with Our Goods and Materials Would save Resources and Energy and Create Local Jobs." *Nature* 531 (7595): 435.

State of Hawaii's Open Data portal. n.d. *Tonnage of Solid Waste Diversion | Data for Hawaii.* Accessed January 11, 2019. https://data.hawaii.gov/Community/Tonnage-of-Solid-Waste-Diversion/dttd-vskk/data.

Stropoly TEC. 2018. *Stropoly TEC Innovation.* July 29. Accessed November 5, 2018. http://www.lcfb-2012.asia/innovation-stropoly-tec.html.

The Product-Life Institute. n.d. "Product-Life Factor (Mitchell Prize Winning Paper 1982)." http://www.product-life.org/en/major-publications/the-product-life-factor.

Tornese, Fabiana, Pazour Jennifer, Andres L Carrano, and Brian K Thorn. 2018. "Improving the Environmental Sustainability of Pallet Logistics Through Preemptive Remanufacturing: an Integer Linear Optimization Model." *15TH IMHRC PROCEEDINGS.* Accessed November 3, 2018. https://digitalcommons.georgiasouthern.edu/imhrc/2018/2018/10/.

United Bottle Group. n.d. *http://www.united-bottle.org/concept.html.* Accessed October 30, 2018.

United States Census Bureau. n.d. *https://www.census.gov/quickfacts/hi.* Accessed October 31, 2018.

Universal Pallets. 2018. *Ultimate Guide To Pallet Markings.* January 18. Accessed October 15, 2018. https://www.universalpallets.com/2018/01/ultimate-guide-pallet-markings/.

Appendix 1

Figure A - 1 Municipal Solid Waste Stream data on Oahu.

Source: www.opala.org

Appendix 2

Figure 98. Kalihi TOD Concept PLan

Source: Kalihi Neighborhood Transit-Oriented Development Plan. March 2017

Appendix 3

Figure 99. Kalihi TOD Concept Plan

Source: Kalihi Neighborhood Transit-Oriented Development Plan. March 2017

Appendix 4

Figure 100. Tax map of the pilot site

Source: City and County of Honolulu, Department of Budget and Fiscal Services Real Property Assessment division. 100

Appendix 5

Figure 101. Residential Shipping Container Primer (RSCP™)